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COLLECTION

OF

RADIO-ACTIVE MINERALS

ACCORDING TO

MME. CURIE.

(Thesis presented before the Faculty of Sciences, Paris, June, 1903.)

The locality from whence a specimen comes is important, no two sources of a mineral affording examples of exactly the same degree of radio-activity. Their external appearance also differs. Hence the number of local examples of several minerals has been increased in this list beyond the number actually described in the thesis. (Three Thorites are omitted.) The localities of the following specimens are not always the same as those of the specimens investigated by Mme. Curie.

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7 Autunite	19 " "
8 Thorite	20 " "
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10 Orangite	22 "
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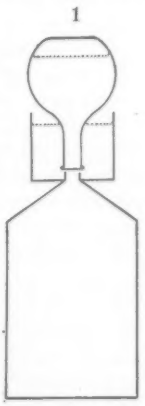
THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VIII.—*On the Properties of a Radio active Gas found in the Soil and Water near New Haven;* by H. A. BUMSTEAD and L. P. WHEELER.

IN the October number of this Journal, the writers published a brief note concerning a radio-active gas which had been found in the surface water near New Haven, in the course of some experiments which had been undertaken at the request of Professor J. J. Thomson. It was stated that the gas obtained from water had the same properties as that which was drawn from a few feet below the surface of the ground; and that both these gases, so far as the experiments had gone at that time, seemed to be identical with the gaseous emanation from radium discovered by Dorn. The purpose of the following investigation was a more careful and direct comparison of these "natural" radio-active gases with the radium emanation, in order to find out whether they contained a small proportion of some other active constituent.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As in Professor Thomson's experiments, the gas was obtained from the water by boiling and, as it was, at best, rather feebly radio-active, it was desirable to prevent its dilution with air as much as possible. The method finally used is sufficiently indicated in fig. 1, and proved to be very convenient. It was suggested by Professor W. G. Mixter, to whom we are also indebted for several other valuable suggestions and for many kindnesses. The earlier tests of the gas were made by means

of a gold-leaf electroscope of C. T. R. Wilson's pattern, in which the leaf is supported by means of a sulphur bead from a rod kept charged to a potential at least as high as that of the leaf; so that any leak of electricity from the leaf must be through the gas and not over the support. A number of control experiments showed that the observed activity was not due to the vessels or drying tubes used, nor to the city supply pipes through which the water reached the laboratory; and the fact that water, once boiled, did not recover to any appreciable extent its power to give off a radio-active gas when left to stand, either stoppered or unstoppered, for two weeks showed that the presence of the gas was not due to contact with the air, nor to a dissolved, or suspended, radio-active solid. The latter conclusion was strengthened by our inability to find any evidence of radio-activity in the solid residue left on evaporating the water. As rain water does not contain a radio-active gas (although it does contain an active solid residue), the only hypothesis which seemed to be left to account for the presence of the gas in this surface water was that the water had come in contact with the gas in its passage through the ground and had dissolved some of it. Accordingly a piece of gas-pipe was driven about 1·5 meters into the earth and its top connected by a rubber tube to a flask filled with water; on allowing the water to run out, the flask became filled with the gas from under ground which was then introduced into the electroscope and tested as before. It proved to be much more active than the gas from water (three or four times for equal volumes) and as it was very easily obtainable in as large quantities as one wished, it was much more convenient to work with.

In order to compare it with the water-gas the rate of decay of the activity of both gases was observed. For this purpose an electroscope was made as nearly air-tight as possible by the use of solder, sealing-wax and asphaltum varnish, and by regrinding the brass cocks with which it was provided; after some difficulty it was made so tight that, upon being partially exhausted, it would lose less than one-half per cent of its exhaustion in 24 hours. When either gas was introduced into this electroscope, an initial rise of activity occurred lasting for about 0·1 day, followed by a regular decay according to an exponential law in which the activity fell to one-half its value in about four days. The curves for the water-gas and for the earth-gas were indistinguishable when reduced to the same scale; one of them is given in fig. 2. During the initial rise, observations of the leak were made as rapidly as possible, and afterward once or twice a day for about two weeks. As the sensitiveness of the gold leaf varied slightly from day to day,

it was tested after each reading by changing the applied potential by 10, 20, and 30 volts and noting the change in deflection; the readings were then reduced to a standard sensitiveness. We are indebted to Mr. H. M. Dadourian for his assistance in making these numerous and somewhat tedious observations.

The resemblance of this gas to the emanation from radium, in respect to the period of initial rise of activity (which is due to the deposition upon the walls of the electroscope of "induced" or "excited" activity) and also in respect to the

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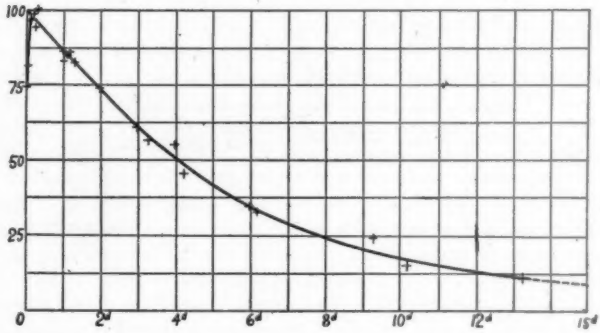

rate at which the activity of the gas itself decays, is so close that we could not hope to detect any differences between the two by means of observations with the electroscope. Accordingly, we had recourse to observations with a quadrant electrometer, and during the autumn, the earth-gas was directly compared by means of the same apparatus with the radium emanation, with regard to the rise of excited activity, the decay of the activity of the gas itself, and the rate of diffusion through a porous plate of unglazed porcelain. The electrometer used was of special construction, made after our design by Mr. L. J. Barrett, mechanician of the Sheffield Scientific School; it proved to be very steady and convenient for the present purpose, and may perhaps be described later, after its behavior under varied conditions has been more fully investigated. When the needle was suspended by a quartz fiber of very moderate thinness, the sensitiveness with 100 volts on the needle was about 250^{cm} per volt, the scale being one meter distant from the mirror. As this was sufficient for our present needs, no attempt to increase it by using a finer suspension was made, particularly as we wished to make observations, in some cases, in as rapid succession as possible and a very large period of the needle was, therefore, undesirable.

A cylindrical condenser (fig. 3), 37^{cm} high and 12·5^{cm} in diameter, was made of heavy galvanized sheet-iron with rings of planished brass, A, and A′, soldered to flanges at top and bottom; at the top, the guard plate, B, rested upon a rubber gasket and was bolted to A by eight small bolts provided with ebonite bushings so that the cylinder was insulated from B, which was kept earthed. The central rod, C, passed through an ebonite collar, D, and the joints about the collar were carefully made tight by sealing-wax. At the bottom, the brass plate, E, was similarly bolted to A′ with a gasket between, but no bushings were needed in this case, and the heads of the bolts were

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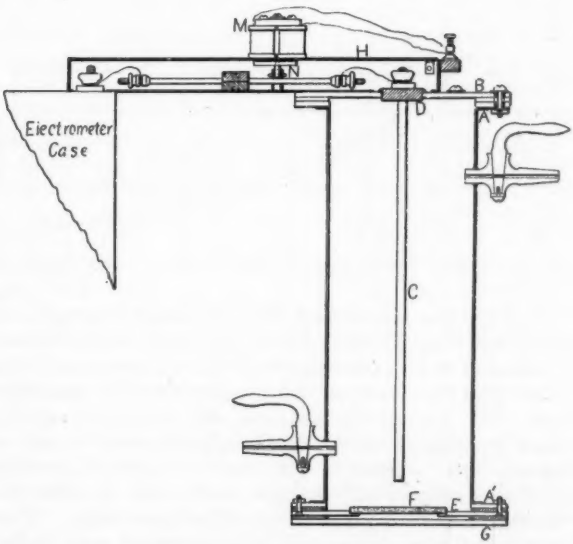

counter-sunk in the bottom surface of E; this plate had a hole in the middle, and above it the porous plate, F, was fastened with sealing-wax. Another plate, G, also provided with a gasket, was clamped below this by eight small iron screw clamps, so that it could be easily removed at any time and the porous plate exposed. The connection to the electrometer was a brass rod supported by ebonite in a rectangular brass box, H, with a hinged lid; this box rested on the guard plate, B, and on the case of the electrometer, and two holes in its bottom admitted the binding screws of rod in the cylinder and of the electrometer. Ordinarily the rod and pair of quadrants connected to it were earthed by N, which was hinged to the box and rested

on the connecting rod; by means of the little electromagnet, M, fastened to the lid of the box, N could be lifted off the rod and the quadrants could thus be insulated without the slightest jar. The short-circuiting contact was made of the same piece of brass on both sides, was small in area, and the distance moved was short; there was thus no trouble from contact potential differences. A small hole through the brass box, opposite the binding screw of the electrometer, enabled one to test the sensitiveness of the electrometer from time to time. When the gaskets were well greased with stiff mutton-tallow, the cylinder retained a pressure in excess of that of the atmosphere without perceptible diminution in twenty-four hours.

The gas to be tested was put into the cylinder and readings were made as rapidly as possible during the rise of the induced activity. After the ionization had reached a steady value, the gas was allowed to stand in the cylinder for several days, and readings were taken from time to time to determine the rate of decay of the activity of the gas; as this change was slow, the average of four readings was taken at each observation. Finally the lower plate was removed and the gas allowed to diffuse through the porous plate, readings being taken as rapidly as possible in the meanwhile. From all these readings the leak due to the so-called spontaneous ionization of the air in the cylinder was always subtracted. The potential applied to the cylinder (90 volts) was more than enough to give the saturation current in all cases. The radium emanation used was obtained by bubbling air through a solution containing 0·1 gram of the very impure radium bromide prepared a year or two ago by De Haen; its activity is about 1000 times that of uranium, so that the solution contained probably less than 0·1 milligram of radium. Three small bubbles drawn through this into the cylinder (perhaps a fifth of a cubic centimeter) caused an ionization about six times as great as 1½ liters of the earth-gas; the chief difficulty with the emanation was to get a small enough quantity into the cylinder.

Comparison of the Rates of Decay.

If we assume the exponential law of decay of the radio-activity $I=I_0e^{-\kappa t}$, the constant κ may be determined from any two observations (or two sets of four observations) taken at different times after the excited activity has ceased to rise. Several such determinations were made for the earth-gas and for the radium emanation and are given in the following tables; t in the formula is measured in hours.

It will be seen that the agreement is well within the limits of accuracy of the experiments. This constant for the radium

Earth-Gas.		Radium Emanation.	
Interval in hours.	κ.	Interval in hours.	κ.
19·31	0·00784	20·00	0·00703
24·32	0·00702	23·31	0·00739
43·63	0·00738	22·61	0·00787
		65·93	0·00745
Av. 0·00741 ± ·00016		Av. 0·00744 ± ·00012	

emanation has been determined by P. Curie* and by Rutherford and Soddy† and, when reduced to the hour as the unit of time, the value obtained by Curie is 0·00724, while Rutherford and Soddy obtained 0·00778. Curie's measurements were made with the emanation in a sealed glass tube, and there could thus have been no acceleration of the apparent rate of decay by escape of the gas. The lower value obtained by us would be accounted for if one-half per cent of the emanation leaked from the cylinder in twenty-four hours. Such a lack of tightness is by no means impossible. Rutherford and Soddy's experiments were made with emanation stored in a gas-holder and drawn off from time to time for testing; a slightly greater rate of leak from their gas-holder might account for the higher value of κ obtained by them.

The Rise of the Excited Activity.

It has been observed by Rutherford that the excited activity due to the radium emanation does not decay according to a simple exponential law, and this we find to be the case also with the excited activity due to the earth-gas. The most practicable method of comparing the two seems therefore to be to reduce the measurements on the two gases to the same scale and to plot a curve for each. Two such curves are found in figs. 4 and 5.

In the reduction to the same scale, the mean of the last four observations has been taken as 100. The following tables give the actual measurements and the plotting scale:

Earth-Gas.

Time in minutes.	Observed ionization.	Plotting Scale.	Time in minutes.	Observed ionization.	Plotting Scale.
3·5	1·98	59·3	92·0	3·21	96·1
12·0	2·28	68·3	102·0	3·08	92·2
20·0	2·49	74·6	121·5	3·42	102·4
26·4	2·62	78·4	139·5	3·35	100·3
33·0	2·60	77·9	223·5	3·36	100·6
42·0	2·75	82·3	240·5	3·36	100·6
62·0	2·86	85·6	273·5	3·21	96·1
76·0	3·05	91·3	284·5	3·43	102·7

* P. Curie, C. R. cxxxv, p. 857, 1902.
† Rutherford and Soddy, Phil. Mag. (6), v, p. 445, 1903.

RADIUM EMANATION.

Time in minutes.	Observed ionization.	Plotting Scale.	Time in minutes.	Observed ionization.	Plotting Scale.
3·0	11·23	52·9	90·75	20·28	95·5
8·1	11·66	54·9	100·75	20·17	95·0
12·75	14·98	70·5	105·75	21·18	99·7
16·75	14·88	70·1	110·75	21·68	102·1
20·75	15·82	74·5	115·75	21·12	99·5
25·75	16·16	76·1	120·75	21·12	99·4
30·75	17·20	81·0	125·75	20·92	98·5
37·75	16·87	79·4	135·75	21·52	101·3
42·75	17·68	83·3	145·75	21·45	101·0
47·75	17·70	83·4	205·75	20·52	96·6
52·75	18·05	85·0	220·75	22·18	104·5
57·75	18·58	87·5	268·75	18·78	88·4
62·75	18·88	88·9	278·75	21·44	101·0
69·75	19·32	91·0	282·75	21·25	100·0
76·75	20·10	94·7	287·75	21·35	100·5
82·75	20·18	95·0	292·75	20·92	98·5

The following values taken from the plotted curve will give an idea of the agreement between the behavior of the two gases:

RISE OF EXCITED ACTIVITY.

Time in minutes.	Earth-Gas.	Radium Emanation.
20	74·6	74·4
40	81·0	81·9
60	86·6	87·9
80	91·6	93·4
100	96·0	97·5

The earlier part of the curves in figs. 4 and 5 ($t < 20$ min.) can not be very accurate. It took about two minutes to introduce the earth-gas, and to make the two experiments as nearly alike as possible the same time was consumed in admitting the radium emanation; the zero of the time scale in the curve is the middle of this interval. Few observations could be taken and the curve is so steep that small errors have a great effect upon the point where the curve cuts the axis. Moreover, the results of the diffusion experiment cannot be reconciled with so small a value of the initial activity of the gas, as will be seen; and a special experiment in which radium emanation was introduced rapidly indicated that the initial activity was between 50 and 60 per cent of the final activity. But the question could not be decided very positively with our apparatus, since the slowness of the return of the needle to its zero did not permit readings to be taken in very rapid succession.

Diffusion through a Porous Plate.

Figures 6 and 7 exhibit the results obtained when the bottom plate was removed and the gas allowed to diffuse through the

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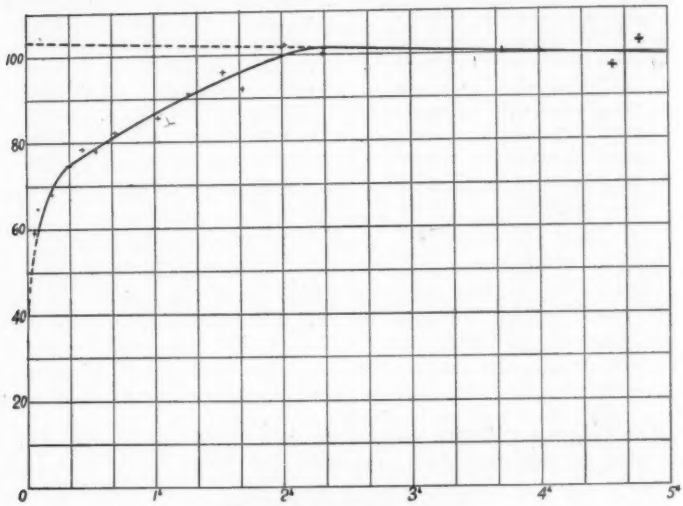

Excited activity; earth-gas.

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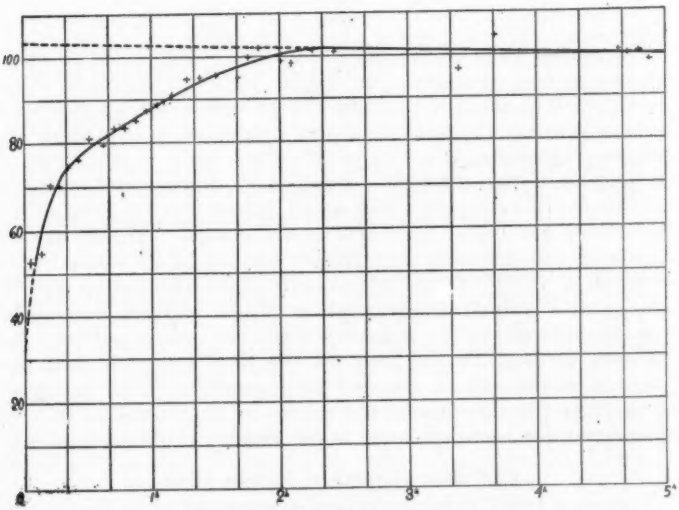

Excited activity; radium emanation.

porous plate; the time is counted from the removal of the plate. As before, the readings are reduced to the same scale, the mean of four readings just before the plate was removed being taken as 100.

EARTH-GAS.

Time in minutes.	Observed ionization.	Plotting Scale.	Time in minutes.	Observed ionization.	Plotting Scale.
0·0	2·81	100·	79·5	1·62	57·7
2·5	2·81	100·	100·5	1·52	54·1
8·0	2·68	95·4	115·5	1·26	44·9
13·0	2·70	96·1	130·5	1·12	39·9
18·0	2·60	92·5	145·5	0·93	33·1
24·0	2·42	86·1	160·5	0·82	29·2
30·5	2·39	85·1	175·5	0·67	23·8
40·5	2·28	81·1	190·5	0·59	21·0
50·5	2·06	73·3	205·5	0·49	17·4
60·5	2·00	71·2			

RADIUM EMANATION.

Time in minutes.	Observed ionization.	Plotting Scale.	Time in minutes.	Observed ionization.	Plotting Scale.
0·0	12·98	100·	59·0	8·92	68·7
4·0	12·43	95 8	64·0	8·32	64·1
8·0	12·08	93·1	69·0	7·26	55·9
11·0	12·20	94·0	74·0	8·04	61·9
17·0	11·47	88·4	102·0	6·38	49·1
21·0	11·26	86·7	110·0	5·52	42·5
26·0	10·99	84·7	115·0	5·72	44·1
31·0	10·61	81·7	119·0	5·28	40·7
37·0	10·44	80·4	226·0	1·84	14·2
50·0	9·34	71·9	230·0	1·72	13·3
54·0	9·14	70·4	235·0	1·64	12·6

The following table taken from the curves gives a comparison of the two gases:

DIFFUSION.

Time in minutes.	Earth-Gas.	Radium Emanation.
20	90·	87·6
40	80·2	76·6
60	70·6	66·0
80	60·5	56·9
100	51·8	48·5
120	43·6	41·2
140	36·0	34·6
160	29·4	28·8
180	23.8	23·7
200	18·9	19·3
220	[14·5]*	15·8
240	[11·0]*	12·0

* Extrapolated.

The agreement is not altogether satisfactory, but the character of the differences would seem to show that they are due to

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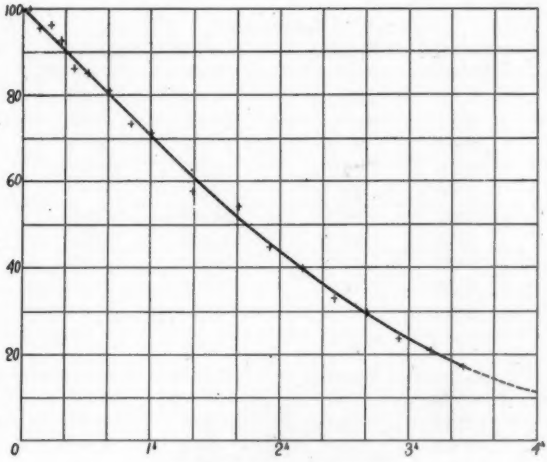

Diffusion of earth-gas.

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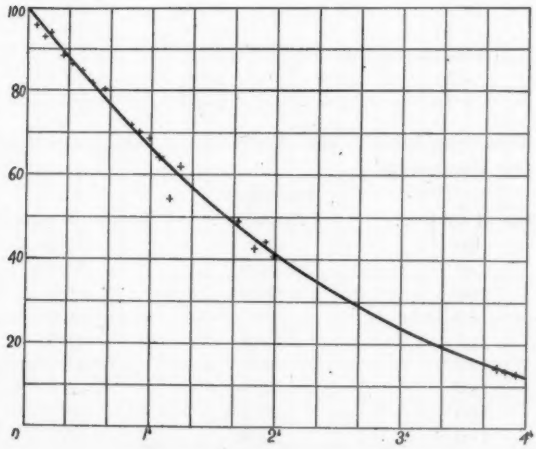


Diffusion of radium emanation.

experimental errors and not to differences in the gases. In the earlier portion of the experiments the earth-gas appears to

diffuse more slowly than the radium emanation and later it diffuses more rapidly. It is difficult to see how this could be the effect of an admixture of either a heavier or a lighter radio-active gas; and the close agreement between the total amounts, diffusing out in four hours (89 per cent and 88 per cent, respectively), together with the close similarity in the rates of decay and of the production of induced activity, show that if any other radio-active constituent is present in the ground air it must be in very small proportion.

Density of the Radium Emanation.

The observations already recorded afford a value of the density of the gas (assuming that Graham's law may be applied) provided the rate of diffusion of a gas of known density through the porous plate is determined. For this purpose carbon dioxide was introduced into the cylinder, allowed to stand until thoroughly mixed with what air remained, and the amount determined by drawing a certain fraction into a burette and absorbing with caustic soda. The porous plate was then exposed for 10 or 15 minutes and the bottom plate again clamped on; after allowing time for thorough mixture, the amount of CO_2 was again determined. Three such observations, with different times of diffusion, gave the following values for μ_1, in the formula $\rho = \rho_0 e^{-\mu_1 t}$ (t measured in hours):

1·18
1·15
1·15

1·16

In the diffusion experiments with the radio-active gas, if it were not for the presence of the induced activity, the curves, figs. 6 and 7, might be expected to be exponential and it would be a simple matter to obtain the corresponding constant, μ, for the radium emanation; but the effect of the induced activity must be taken into account, and this is the more difficult since its rise and decay is not susceptible of a simple mathematical expression. In fact, as Rutherford has pointed out, there are probably two or three different kinds of induced activity, in the case of radium, each being produced and decaying at a different rate. In order to make the calculation somewhat more manageable, it is assumed in what follows that the rise and decay of the induced activity does follow the exponential law; it will be seen in the outcome that this assumption cannot cause a very serious error in the determination of the diffusion constant.

Let

A = ionization produced by the gas at any instant.
E = " " " excited activity.
I = observed ionization.
So that $I = A + E$.

As a result of the regular decay of the activity of the gas itself we have

$$A = A_0 e^{-\kappa t}$$

Assuming that we have only one kind of excited activity, its rate of production is proportional to the quantity of gas present, i. e. to A; and its rate of decay is proportional to E, so that

$$\frac{dE}{dt} = aA_0 e^{-\kappa t} - \lambda E \qquad (1)$$

Taking $t = 0$ as the time when the gas is introduced into the cylinder, the solution of this equation is

$$E = \frac{aA_0}{\lambda - \kappa}\left(e^{-\kappa t} - e^{-\lambda t}\right)$$

and the total observed effect is

$$I = A_0\left\{\left(1 + \frac{a}{\lambda - \kappa}\right)e^{-\kappa t} - \frac{a}{\lambda - \kappa}e^{-\lambda t}\right\} \qquad (2)$$

As we have seen, $\kappa = 0{\cdot}0074$ when t is measured in hours, and $\lambda = 1{\cdot}36$ gives an exponential rise of excited activity not greatly different from that observed in figs. 4 and 5; so that during the first two or three hours $e^{-\kappa t}$ is nearly equal to unity, and we have approximately

$$I = A_0\left\{1 + \frac{a}{\lambda - \kappa}\left(1 - e^{-\lambda t}\right)\right\} \qquad (2')$$

The curve expressed by (2) differs from (2′) in that its asymptote is not a horizontal straight line but the curve,

$$A_0\left(1 + \frac{a}{\lambda - \kappa}\right)e^{-\kappa t};$$

and within the time considered this is sensibly an inclined straight line which is shown in figs. 4 and 5; $\frac{a}{\lambda - \kappa}$ is the ratio of the excited activity, after equilibrium has been attained, to the activity of the gas.

After three or four hours $e^{-\lambda t}$ is negligible in comparison with $e^{-\kappa t}$ so that we have sensibly

$$I = A_0\left(1 + \frac{a}{\lambda - \kappa}\right)e^{-\kappa t} \qquad (3)$$

and this justifies the determination of κ by the method pursued above, without regard to the induced activity.

In discussing the diffusion experiment, it is convenient to take the initial instant ($t=0$) as that when the diffusion begins; we have then

$$\frac{dA}{dt} = -\kappa A - \mu A$$

where μ is the diffusion constant for this gas through the porous plate used, and thus,

$$A = A_0 e^{-(\kappa+\mu)t}$$

and

$$I_0 = A_0 + E_0 = A_0\left(1 + \frac{a}{\lambda-\kappa}\right)$$

as before,

$$\frac{dE}{dt} = aA - \lambda E$$

which under the assumed initial conditions gives

$$E = \frac{aA_0}{\lambda-\kappa-\mu}\left\{ e^{-(\kappa+\mu)t} - \frac{\kappa+\mu}{\lambda-\kappa} e^{-\lambda t}\right\}$$

and

$$I = A_0\left\{\left(1 + \frac{a}{\lambda-\kappa-\mu}\right)e^{-(\kappa+\mu)t} - \frac{a}{\lambda-\kappa}\frac{\kappa+\mu}{\lambda-\kappa-\mu}e^{-\lambda t}\right\} \quad (4)$$

and by properly choosing the value of μ this should fit the observations plotted in figs. 6 and 7. In order to get a first approximation to μ we may make use of the initial slope of the curve:

$$\left(\frac{dI}{dt}\right)_{t=0} = -A_0(\kappa+\mu)\left\{1 - \frac{a}{\lambda-\kappa-\mu}\left(1 - \frac{\lambda}{\lambda-\kappa}\right)\right\} \quad (5)$$

and since κ is so small in comparison with λ, we have approximately

$$\left(\frac{dI}{dt}\right)_{t=0} = -A_0(\kappa+\mu) \quad (5')$$

As has been pointed out, the value of A_0, that is the activity of the gas itself without the induced activity, is very imperfectly known. If we take the values indicated by the extensions of the curves in figs. 4 and 5 (30 to 40 per cent of the

total), the value of μ obtained from equation (5′) when substituted in (4) will not fit the observations. On the other hand, if it be assumed that between 50 and 60 per cent of the total activity is due to the gas, a reasonably good fit can be secured; and this value of A_0 is also indicated by a special experiment under better conditions in which a larger quantity of radium emanation was admitted rapidly; but even under the best conditions with the electrometer used, readings could not be obtained oftener than every $2\frac{1}{2}$ minutes, and thus the principal weight in the selection of a value for A_0 must be given to the diffusion curve. It is to be noted that the constant, a in (4), as determined from experiment, depends on the value chosen for A_0.

In the following table the second column is calculated from equation (4) with $A_0=56$, $\lambda=1{\cdot}36$, $\mu=0{\cdot}58$, which value gives a better fit than either 0·57 or 0·59. The third column gives the experimental values for the radium emanation as determined from the curve, fig. 7.

Time in hours.	Calc.	Curve.	Diff.
1	67·5	66·0	+1·5
2	40·2	41·2	−1·0
3	23·6	23·7	−0·7
4	12·9	12·0	−0·9

The differences are considerably less than the differences between the experiments for the earth-gas and the radium emanation; for the former, $\mu=0{\cdot}56$ appears to give the closest agreement. If we take 0·57 as the value from the two experiments and assume that Graham's law may be applied, we find that the density of the gas is 4·1 times that of carbon dioxide, which would give it a molecular weight of 180.

As our apparatus was conveniently arranged for use with radio-active gases, we attempted to determine the properties of the active gas recently obtained by Strutt* from metallic mercury. We were, however, unable to obtain any evidence of radio-activity from air which had been circulated through hot mercury for fourteen hours; and an increase of ten per cent over the "spontaneous" ionization in the cylinder could certainly have been detected. This would seem to indicate that the gas observed by Strutt was due to some radio-active impurity in the mercury which he used.

In connection with the evidence of the existence of minute quantities of radium in the ground in this vicinity, it is of

* Strutt, Phil. Mag., July, 1903.

interest that small quantities of pitchblende and other uranium minerals are found in Connecticut. The fact, however, that the gas, originally discovered by Professor Thomson in the Cambridge water, has also been found to be mainly, if not wholly, radium emanation,* and that the gas found by Elster and Geitel† in the soil in various places in Germany has the same general characteristics, make it not unlikely that radium may be very widely distributed in the earth, although not always in the surface layers.

Conclusions.

1. The radio-active gas found in the ground and in the surface water near New Haven is apparently identical with the emanation from radium. If any other radio-active constituent is present it can be only in very small proportion.

2. The density of the radium emanation, as determined by its rate of diffusion, is about four times that of carbon dioxide.

3. We were unable to obtain the radio-active gas from mercury, recently described by Strutt, and are therefore inclined to attribute his results to an impurity in the mercury used.

Sheffield Scientific School of Yale University, December, 1903.

* E. P. Adams, Phil. Mag., Nov., 1903.
† Elster and Geitel, Phys. Zeitsch., July 1, 1903.

ART. IX.—*Structure of the Upper Cretaceous Turtles of New Jersey: Adocus, Osteopygis, and Propleura;* by G. R. WIELAND. (With Plates I–IX.)

ONE of the most striking geologic features of New Jersey is the area of Upper Cretaceous Greensand or "Marl" which extends obliquely across the state from the Delaware Bay to Sandy Hook. Few Mesozoic formations yield a richer series of extinct vertebrates; and amongst these, the Testudinates, as here so well represented by marine, littoral, and doubtless land forms, are of great interest and importance from a biologic point of view.

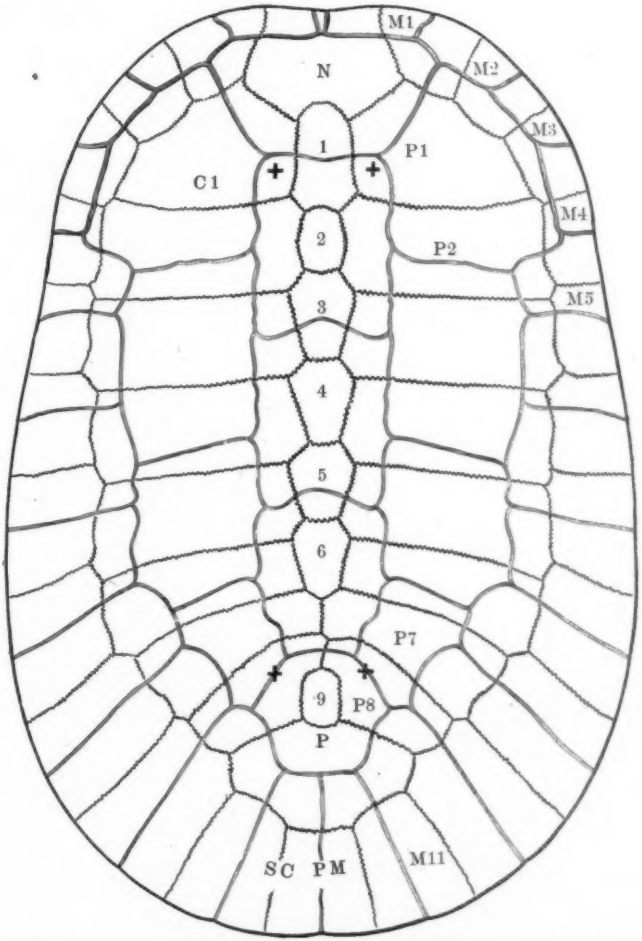
These turtles mainly occur in the "Greensand" with the bones of birds, pterodactyls, dinosaurs, crocodiles, mosasaurs, gigantic fishes, and sharks, not many feet below a prominent and extensive bed of Gryphæas, preceded and followed by marls. There are implied abruptly changing conditions and a near shore; and there is a constant likelihood that there may here be found primitive marine or littoral turtles presenting characters allied to those of the old stocks from which the original marine turtles were derived, a fact which needless to say gives to the investigation of the specimens from the Greensand an exceptional value. For amongst the fundamental skeletal changes exhibited by extinct forms, none are more interesting than those connected with the evolution of flippers. Moreover the manner in which this took place in the turtles is rapidly nearing very complete demonstration. As yet, however, the structure of the Upper Cretaceous turtles of New Jersey has received but brief attention.

The carapace of *Adocus* as figured by Professor Marsh some years since, has made this the best known of these forms. But with this exception the descriptions and figures so far as given have been based on fragmentary material, and there has been little evidence presented as to the character of the limbs. Nevertheless the sand matrix, and the naturally disarticulated and uncrushed condition of the skeletal elements of these fossils (see Plate IX), afford the opportunity for rarely satisfactory study. In the following initial descriptions a more adequate knowledge of three of the genera is for the first time made available.

I. *Adocus punctatus* MARSH.—(With Plates I–IV.)

The genus *Adocus* was first assigned by Cope* to some fragmentary remains from the Upper Cretaceous or Greensand of New Jersey, these having been originally described by Leidy

* Proceedings of the Academy of Natural Sciences, Philadelphia, 1868.



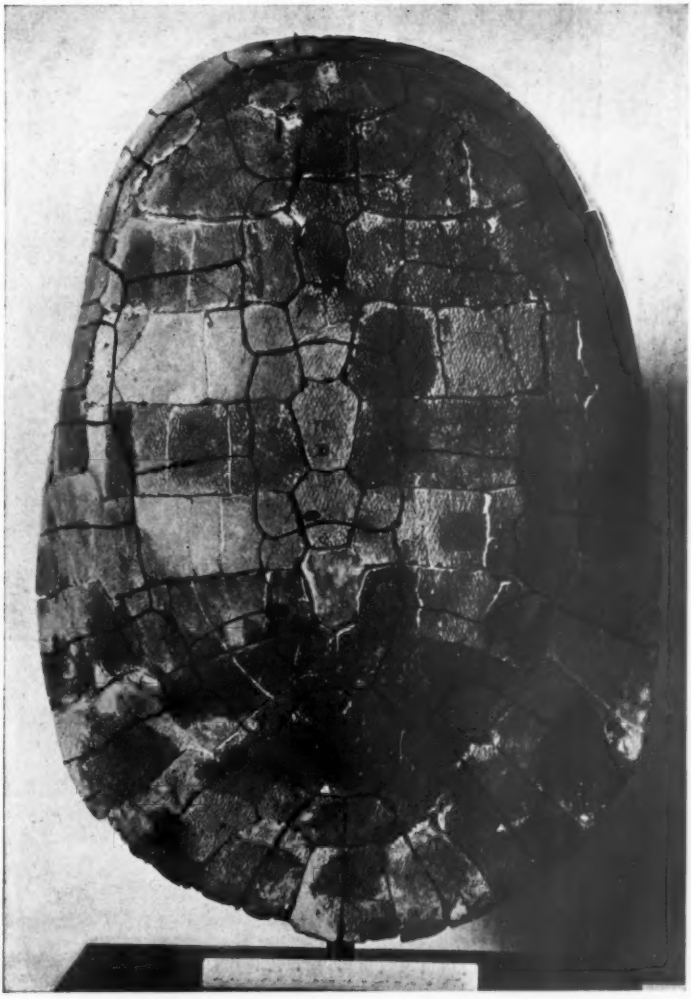
CARAPACE OF ADOCUS PUNCTATUS Marsh, $\times \frac{1}{4}$.—Drawn from type.

(a) Bone Plates.—N, Nuchal; 1–6, 9,–1st–6th, and true 9th Neuralia; P, Pygal; Pm, Pygal Marginal; P1, P2, P7, P8,–1st, 2d, 7th and 8th Pleuralia; M1–M5, M11,–1st–5th and 11th Marginals.

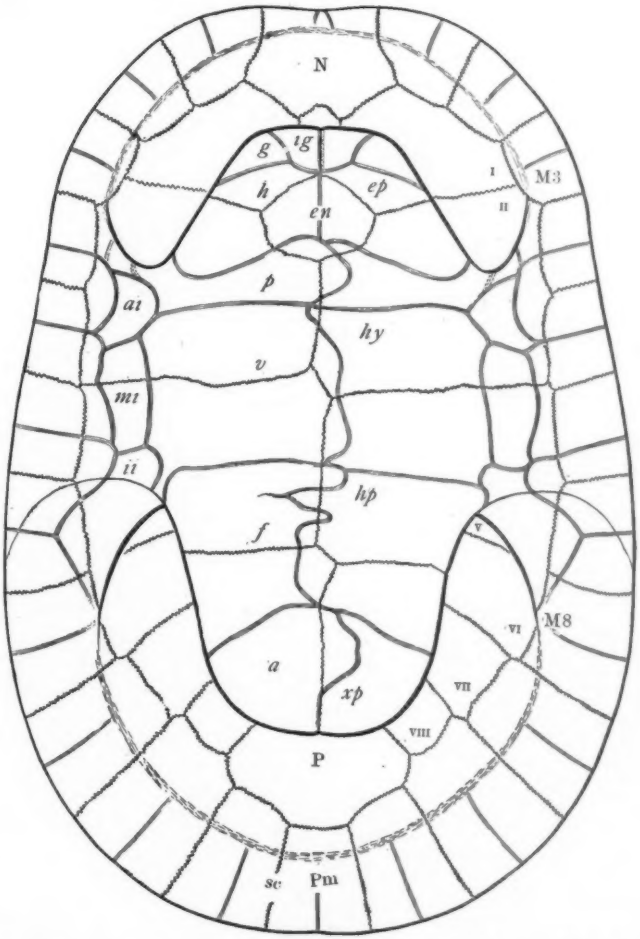
(b) Horn Shields.—N and 1, 1st Vertebral; 2 and 3, 2d Vertebral, etc.; C1, the 1st of the four Costals; M1–M5, 1–5 Marginalia; SC, supra caudal.

(+) Anterior, point at which the first and second ribs unite with 1st Pleural.

(+) Posterior, point at which rib of tenth dorsal vertebra unites suturally with the 8th Pleural, or else point of iliac support.



CARAPACE OF ADOCUS PUNCTATUS Marsh (type).
(Actual length, 54 cm.)



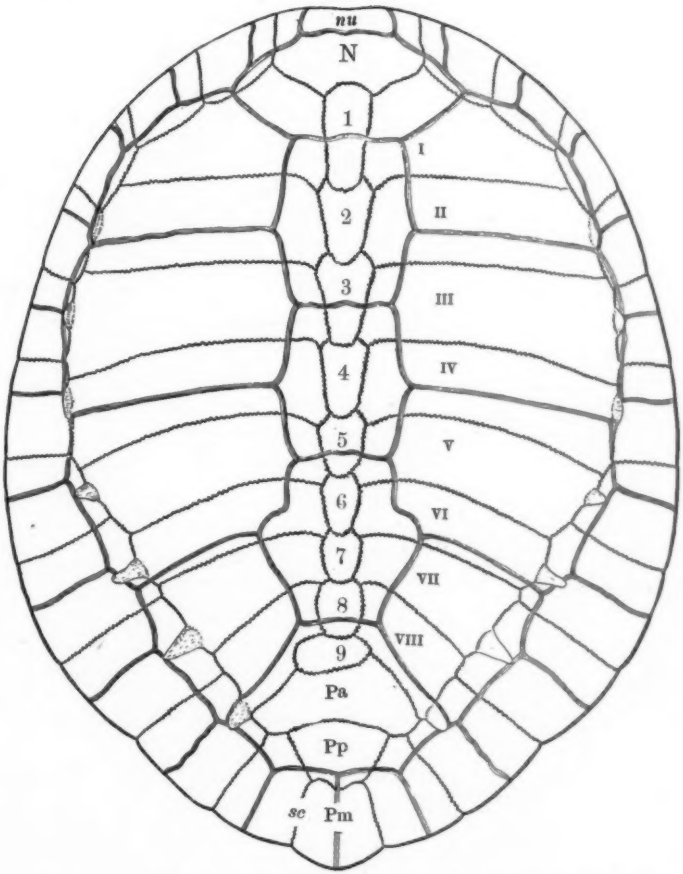
PLASTRAL VIEW OF ADOCUS PUNCTATUS Marsh, × ½.—Drawn from type.

Plastron.—(a) Bone Plates:—*ep*, Epiplastron; *en*, Entoplastron; *hy*, Hyoplastron; *hp*, Hypoplastron; *xp*, Xiphiplastron. (b) Horn Shields:—*ig*, Intergular; *g*, Gular; *h*, Humeral; *p*, Pectoral; *v*, Ventral; *f*, Femoral; *a*, Anal; *ai*, *mi*, *ii*, axillary, mesial and inguinal infra-marginals.

Carapace.—M3, 3d Marginal supporting axillary buttress of Plastron; M8, 8th Marginal supporting inguinal buttress of Plastron; N, Nuchal; P, Pygal; Pm, Pygal Marginal; I, II, V–VIII, 1st, 2d, 5th–8th Pleuralia; *sc*, supracaudal horn shield.

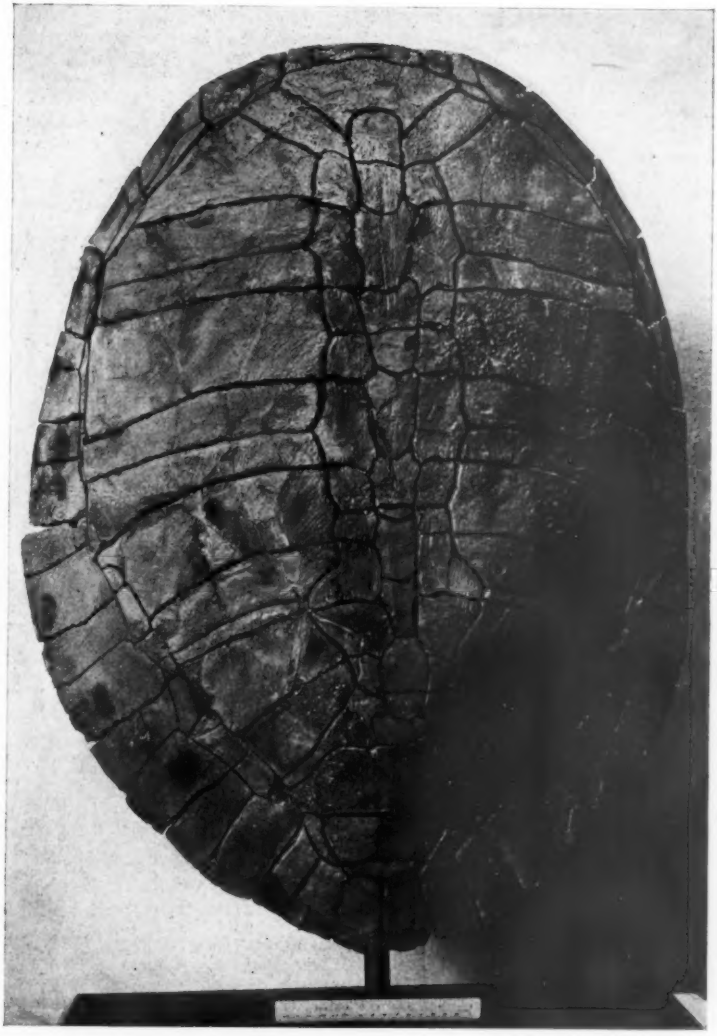
ADOCUS PUNCTATUS Marsh.

Plastral view of type.—Entire length of specimen, 54 cm.

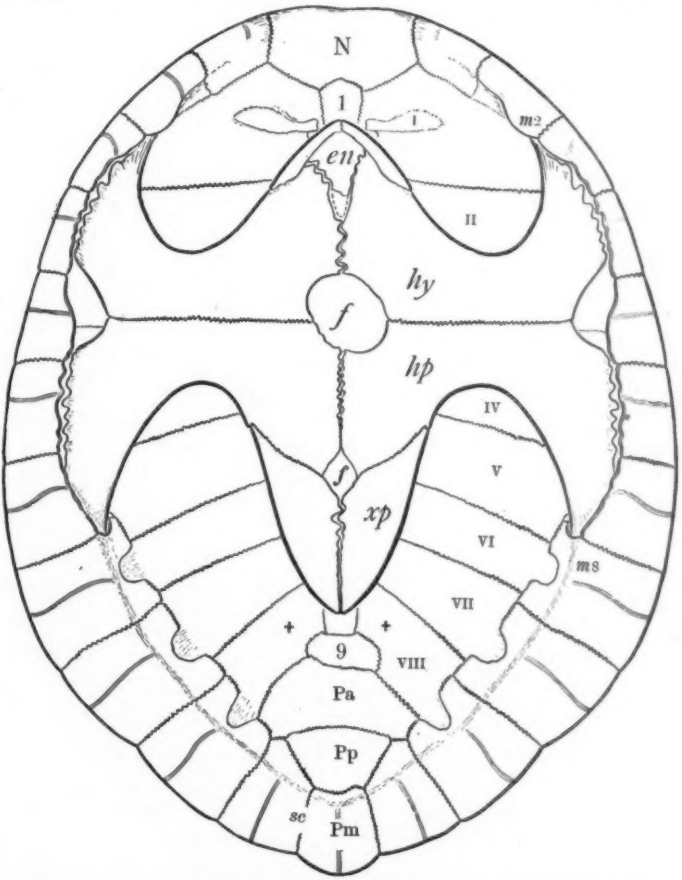


CARAPACE OF OSTEOPYGIS GIBBI Wieland, $\times \frac{1}{6}$.—Drawn from type.

N, Nuchal; 1–9, 1st–9th Neuralia; Pa, Pygal, anterior; Pp, Pygal, posterior; Pm, Pygal Marginal; I–VIII, 1st–8th Pleuralia; *nu*, nuchal horn shield; *sc*, left supracaudal horn shield.—Bony plates in saw-tooth, and horn shields in triple line border.



CARAPACE OF OSTEOPYGIS GIBBI Wieland (type).
Actual length, 74.3 cm.

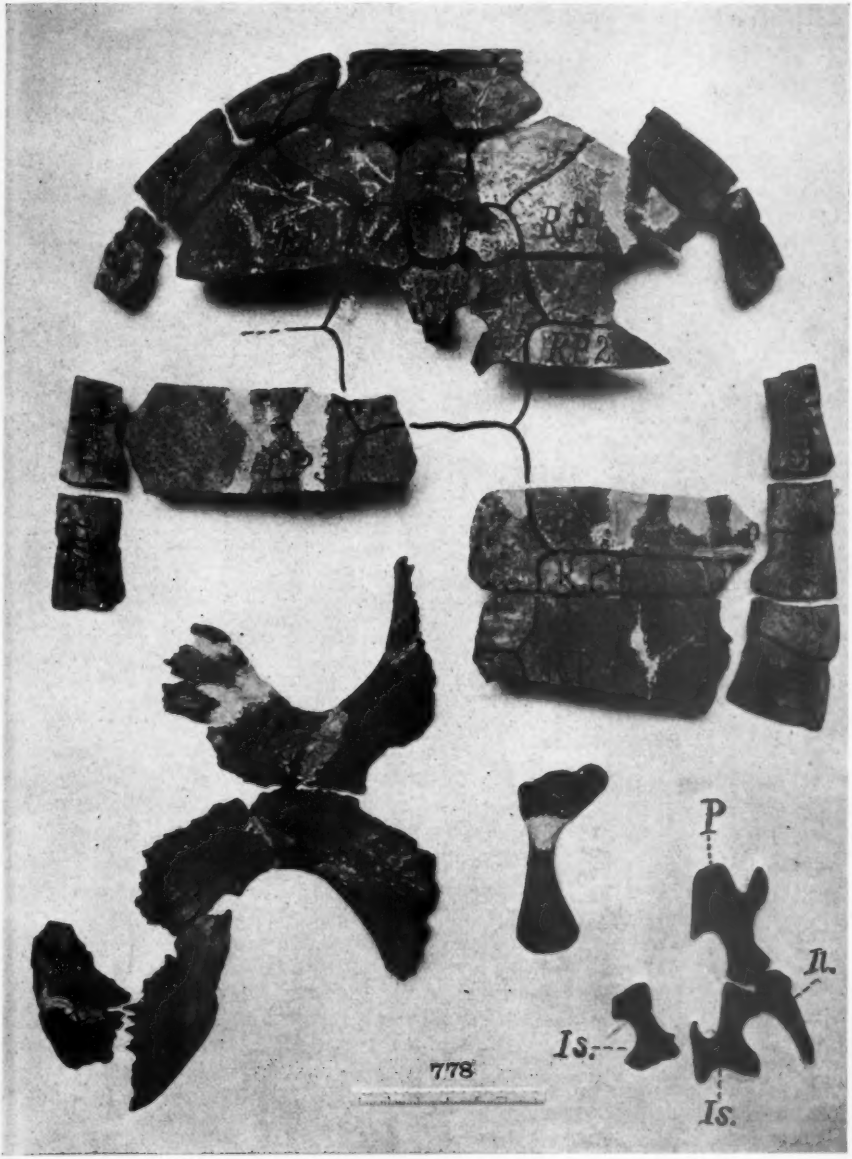


PLASTRAL VIEW OF OSTEOPYGIS GIBBI Wieland, $\times \frac{1}{6}$.—Drawn from type.

en, Entoplastron; *hy*, Hyoplastron; *hp*, Hypoplastron; *xp*, Xiphiplastron; *f*, *f*, Plastral Foramina; *m*2, axillary buttress and 2d Marginal; *m*8, inguinal buttress and 8th Marginal; N, Nuchal; 1, 9, 1st and 9th Neurals; Pa, Pygal, anterior; Pp, Pygal, posterior; Pm, Pygal Marginal; I, First Rib; II, IV–VIII, Pleuralia; (+), point of iliac support on 8th pleural; *sc*, supracaudal horn shield.

OSTEOPYGIS GIBBI Wieland.

Plastral view of type.—Entire length of specimen, 74.3 cm.



PROPLEURA BOREALIS, sp. nov. $\times \frac{1}{4}$.

N, Nuchal; 1, 2,—1st and 2d Neurals; Lm 1-3, 5, 6,—Left Marginals; M2, 3, 5-7,—Right Marginals; R. P. 1, 2, 4. 5,—Right Pleurals; L. P 1, 3,—Left Pleurals; H, Hyoplastron; Hp, Hypoplastron: X, X,—Xiphiplastra; L H, Left Humerus (dorsal view); P, Pubis; Il, Ilium; Is, Ischia.—Nuchal, and 1st and 2d vertebral horn shields, in ink outline.

as *Emys beatus*. The name *Adocus* (Gr. A, privative; and Δωχος, rafter) meaning literally without rafters, happily expresses the fact that the rib heads (with the exception of the first and second and tenth) are diminished to the merest line-like trace on the inner surface of the pleurals. The general characters of the genus, however, remained but vaguely known until the description of the carapace of the new species *Adocus punctatus* by Professor Marsh.* This was accompanied by an excellent woodcut, which is here reproduced. fig. 1.

1

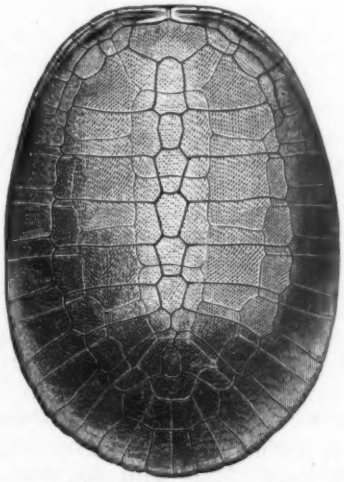


FIGURE 1.—*Adocus punctatus* Marsh (type). Carapace × ½.—The original figure by Professor Marsh.

Later the type was placed on exhibition in the Yale University Museum, although no attempt was made to bring the carapace and plastron into their normal position until recently. This having now been done, and this fine type having again been placed on exhibition as finely mounted in erect position by Mr. Hugh Gibb, an opportunity is afforded to supply the much needed figure of the plastron, and present further facts and figures showing the true form of this ornate and interesting Cretaceous turtle.

The remounting of the specimen proves that the outline of the carapace departs from the oval form shown in the original

* Notice of Some Extinct Testudinata. This Journal, vol. xl, 178 and 9, 1890. The type is from the long since abandoned pits of the old Cream Ridge Marl Co. near Hornerstown, Monmouth Co., New Jersey, and was received at the Yale Museum, Oct. 10, 1872.

figure, by a distinct narrowing in the anterior region, so that the greatest breadth is seen two-thirds of the entire length back. A very slight double curvature of the outer border also appears to be present, as shown in Plate 1. It is found, too, that there is less flattening of the carapace than is suggested in figure 1, the curvature rather closely approaching that of *Dermatemys mawii*.* The unusual heavy furrow marking the boundary between the first vertebral and first pleural, also between these two elements and the nuchal and first four marginal horn shields, is shown in the orignal figure, as well as in the additional outline figure (Plate 1) drawn by the writer from the remounted specimen. In the latter figure the sutures are indicated by the serrate lines, and the boundaries of the horn shields by a triple line. With the prominent exception just noted, the other boundaries of the horn shields, though distinct, are indicated by a narrow and shallow groove only. The finely punctate sculpturing of the surface of the carapace is fairly well shown in Plate II, reproduced from a photograph. The punctations are of sub-triangular outline. They appear nearly as if made by the slightly blunted corner of a chisel blade, and approach regularity in their distribution.

The *plastron*, like the carapace, has a punctate surface. The preservation is also exquisite, and the complete trace of all the bony plates and horn shields may be accurately determined, as shown in my outline drawing, Plate III.

Synopsis of the Characters of Adocus.

Carapace.—Of rather elongate sub-elliptical outline, and composed of 48 bony plates with the grooves marking the borders of the 38 horn shields distinct, as follows:—

(*a*) Bony Plates: Marginals 11 pairs, large and heavy, the inner borders uniting solidly with other elements by suture; nuchal large, of sub-pentagonal outline and without nether or costiform processes; pygal as large as nuchal, and of sub-octagonal shape, its boundaries being the 9th neural, 8th pleurals, 11th pair of marginals, and the intervening pygal marginal; pygal marginal large and of sub-quadrilateral form; pleurals 8, the 2d–8th being without rib capitulæ, and the 7th and 8th meeting on the median line; neurals, 7 in all,—there being no true 7th and 8th, *the true 9th* following the interim formed by the median junction of the 7th and 8th pleurals.

(*b*) Horn Shields: A diminutive nuchal and 12 paired marginals, the first four pairs being intermediate in width between the same elements in *Osteopygis* and *Chelydra*, *and the others of large area rising high on the carapace;* 5 vertebralia; 4 pairs

* Table XXI, Gray's Catalogue of Shield Reptiles, Part I. London, 1855.

of costals, the first pair being large and overlapping the inner ends of marginals 1–4; the second and third of nearly the same area, width, and length as the second and third vertebrals. Unlike the 1st, the 2d–4th costals lie entirely on the pleuralia.

Plastron.—Of medium size, the length being two-thirds, and the least width of the bridge one-fourth that of the carapace. Anterior and posterior borders not emarginate, but slightly truncate or "abbreviated." Very heavy, and united to the carapace by sutures (cleidosternal union), with the strong axial and inguinal buttresses meeting respectively the 3d and the 8th marginalia. Composed of 9 heavy bony plates all strongly united by suture, with the narrow line-like furrows marking the borders of the twenty horny shields distinct.

(*a*) The *Bony Plates:* There are the usual eight paired plastrals with a rather large entoplastron of sub-hexagonal outline, and completely enclosed by the epi- and hyoplastra. The heavy axial buttress extends forward to the posterior portion only of the inner edge of the third marginal, and the large inguinal buttress (peduncle) backward to the anterior portion of the inner border of the 8th marginal. The inferior inner borders of these and the intervening 4th, 5th and 6th and 7th marginals pass well in to meet the plastral elements, and the bridge is firmly anchylosed.

(*b*) The *Horn Shields:* Intergular separated by a furrow or semi-divided into paired parts; gulars of sub-isosceles triangular outline; humerals meeting on a straight mesial line; but pectorals, ventrals, femorals and anals on an irregularly sinuous line crossing and recrossing the median sutural junction of the bony elements beneath; three paired inframarginals, axial, mesial and inguinal, with an indistinct small fourth pair well down in the humeral notch. All outlines indicated by fine lines or narrow grooves.

Adocus punctatus a Distinct Species.

In his original description Professor Marsh stated that the present type was most like *A. beatus* of Leidy, and the identity of these species has since been claimed by several. I find however, on comparing the figures of Leidy's type,* that specific differences are to be made out even from the fragmentary materials which constitute it. To make these clear, I show in figure 2 (*a* and *b*) the first left marginals of the forms in question. They are not of the same proportion, nor are the vertebral and marginal horn shields of so nearly the same outline as they would normally be in one and the same species.

* * * * * * *

* Leidy, Cretaceous Reptiles of the United States (Philadelphia, 1865), Plate XVIII, figures 1–3.

As pointed out by Marsh and later by Baur,* the nearest living relative of *Adocus* (the type genus of the Adocidae of

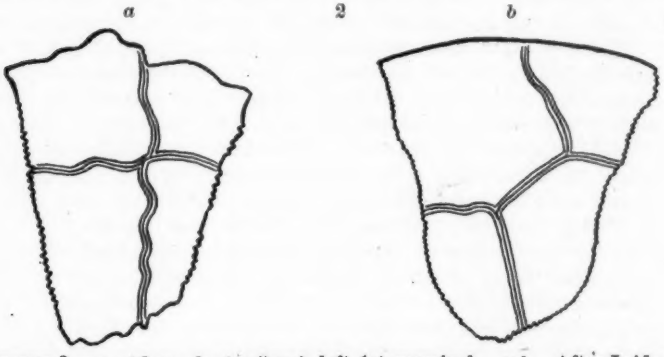


FIGURE 2.—*a. Adocus beatus* (type), left 1st marginal. ×⅓. After Leidy.
b. Adocus punctatus, Marsh (type), left 1st marginal. ×⅓.

Cope†) is *Dermatemys* of Yucatan, which with the genera *Staurotypus* and *Claudius* of Mexico and Central America, constitute the *Dermatemydidæ*.

The arrangement of the neuralia of *Dermatemys* is much the same as in *Adocus*, but there are only 46 plates in the carapace as figured by Boulanger (Brit. Mus. Cat.), the 7th pleural being large and representing the 7th and 8th of *Adocus*. Also, not only the first, but all the succeeding costals overlap the marginals. *Dermatemys* likewise differs markedly in the presence of a costiform process of the nuchal.

Four inframarginals are present, but there are no separate paired gulars as in *Adocus*. Unlike the latter, the plastron is notched posteriorly.

Measurements of Adocus punctatus Marsh (type).
Skeletal parts uncrushed.

(1) *The Carapace.*

Length on straight line	54.	cm
Length over curvature	60.	
Greatest width (across 5th neural)	37.	
Distance over curvature across 5th neural	51.	
Projection beyond front end of plastron	6.8	
Projection beyond hinder end of plastron	12.2	

* Proceedings of the Academy of Natural Sciences, Philadelphia, 1891, vol. xliii, p. 428–430.
† Proc. Amer. Phil. Soc., Philadelphia, 1870, xi, p. 515.

(2) *Bony Plates of the Carapace.*

	Length along outer edge of Carapace.	Middle length from lower edge of Carapace to interior borders.
Nuchal	6·5 cm	7·2 cm
1st Marginal	6·5	6·5
2d "	5·5	6·5
3d "	5·0	6·2
4th "	4·8	7·0
5th "	5·5	8·5
6th "	6·0	9·3
7th "	6·8	9·5
8th "	7·5	9·8
9th "	6·5	9·6
10th "	6·8	9·4
11th "	6·5	7·0
Median	6·8	6·3

	Length (antero-posterior).	Greatest width (lateral).
Nuchal	6·5	7·2
1st Neural	7·0	4·0
2d "	4·0	2·9
3d "	5·2	3·9
4th "	4·8	3·8
5th "	4·2	3·9
6th "	4·7	3·7
9th "	3·6	2·3
Pygal	7·2	11·2

	Length (laterally).	Width (across middle of plate).
1st Pleural	10·0	8·2
2d "	13·5	5·2
3d "	14·5	5·2
4th "	15·0	5·0
5th "	14·8	4·6
6th "	13·0	4·5
7th "	12·0	3·9
8th "	10·4	4·4

(3) *Carapacial Horn Shields.*

Length of 1st–11th Marginalia respectively, along outer edge of carapace, 6·2, 6·2, 5·1, 5·0, 5·3, 6·0, 6·3, 7·2, 7·5, 7·3, 7·0, 6·8 centimeters.

Length of 1st–4th Costalia respectively, 12·6, 11·8, 10·0, 7·2 centimeters.

Length of the Nuchal scute, 1·6.

Length of the 1st–5th vertebralia respectively, 10·2, 9·1, 10·4, 10·2, 8·3 centimeters.

(4) *Elements of the Plastron.*

	Greatest length on median line.	Greatest lateral width.
Epiplastron	2·5cm	6·5cm
Entoplastron	5·0	6·8
Hyoplastron	6·0	14·0
Hypoplastron	10·5	14·0
Xiphiplastron	11·	8·

(5) *Plastral Horn Shields.*

	Greatest length on median line.	Greatest lateral width.
Intergular	2·5	3·
Gular	(3·)	(4·)
Humeral	4·	8·5
Pectoral	4·	11·
Ventral	9·0	11·
Femoral	8·5	9·
Anal	7·5	7·

(6) *Thickness of various elements.*

Nuchal (at anterior median border)	1·1cm
" (at posterior end)	·3+
1st Neural (at anterior end)	·4
1st " (at posterior end)	1·0
5th " (anterior)	1·0
5th " (posterior)	1·0
7th " (average)	·5
1st Marginal (at the marginal–vertebral–costal horn shield intersection)	2·0
11th Marginal	1·3

II. *Osteopygis Gibbi* sp. nov.—(Plates V–VIII.)

The genus *Osteopygis* was proposed by Cope in 1868* for the reception of certain fossil turtles from the Upper Cretaceous Greensand Bed of New Jersey. In all some seven species have been referred to this genus. But they are quite without exception based on fragmentary material, for the greater part insufficiently illustrated and described. It is hence with the utmost difficulty, if at all, that one may adjudge the value of the several species without having at hand all of the types, which urgently require redescription and adequate illustration. This being the fact, the restoration for the first time of the complete shell of *Osteopygis* must be of immediate service and interest. The possibility of such a restoration is afforded by Yale Specimen No. 783.

* Proceedings of the Academy of Natural Sciences, Philadelphia, 1868, p. 147.

This finely preserved Carapace and Plastron is accompanied by a perfect right Femur and left Humerus, with the proximal end of the left Femur, the distal end of the right Humerus, a perfect left Ulna, both ends of the Tibia, the first and second left Metatarsalia, the 7th Cervical centrum, and some fragmentary cervicals.

All the parts just enumerated are believed to belong to one and the same individual. Lest the question should be raised, I state that the Carapace and Plastron are not composite. It was proven that every portion belonged to the same individual.

As now mounted and shown in Plates VI and VIII, almost the only restoration required was due to the loss of portions of the originally complete shell, at the time of collection. Fortunately, in no case is such restoration hypothetical. Invariably the outlines are delimited by unbroken opposing surfaces or articulations. The most serious loss was in the case of several of the neuralia, of which portions of the first and third, and all of the sixth–ninth were lost; but, fortunately, opposed sutural unions of these parts with the pleuralia indicate the outlines of all these bones. The pleuralia are practically complete, and neatly join. All the marginalia but the left 11th are present, complete, uncrushed, and suturally interlocked. As will be noted, the 9th neural and the anterior pygal are both distinctly assymmetric.

That the accompanying limb bones belonged to this particular carapace and plastron, is indicated by all the available evidence. When I began the study of this fossil as received with its various parts dissociated and some of them broken, I found accompanying it and bearing the same catalogue number, 783, a differently weathered left hyoplastral fragment, and a perfect left hypoplastron of the same size, and plainly of the same species as the plastron belonging to the carapace. In addition, there were most of the pleuralia, and several marginals of a much smaller turtle belonging to the genus *Lytoloma*, a much more distinctly marine form. None of these turtles can possibly be confused with the individual here described, and they constitute all the parts of the original shipment, as received from the West Jersey Marl Company of Barnsboro, Gloucester Co., New Jersey, May 17, 1870. These turtles came from the large marl pits, in the "Upper Greensand Beds," one and one-half miles east of the Barnsboro P. O., at which digging was abandoned about twenty years ago.

The present specimen, or 783 proper, clearly belongs to the genus *Osteopygis*, as commonly used. Though, of course, as Cope himself pointed out, this genus may ultimately be referred

to the prior one, *Euclastes.** For reasons given below, the species is considered a new one, and I take great pleasure in naming it in honor of Mr. Hugh Gibb, Preparateur at this Museum for more than twenty years past, and an excellent naturalist.

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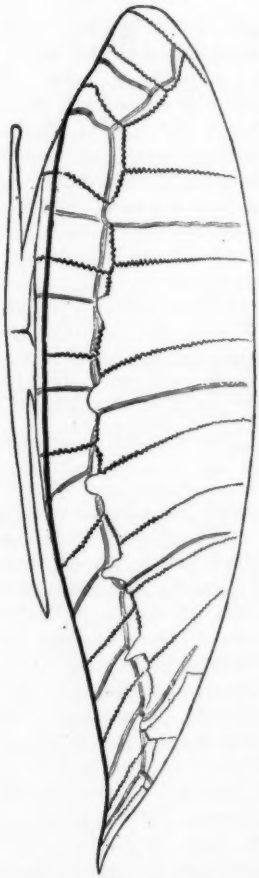

FIGURE 3.—*Osteopygis Gibbi* (type). Sketch of the lateral view of the carapace and plastron as mounted. × ⅙.

Description.—The general outline of the Carapace is broadly subelliptical, the nuchal having only slight recurvature, and the pygal region forming a very obtuse angle.

As may be seen by referring to the side view, figure 3, the body is rather flat. The general outline is not unlike that of *Kachuga lineata*, the plastron being, however, much flatter and quite different. To get any comparison of plastral form, it is necessary to turn to the Dermatemydidæ or to *Chelydra*. The very large posterior marginals rise at a rather low angle. The surface of the bony plates is seldom pitted, except by accident, and is, especially over a large portion of the pleuralia, marked by closely set fine lines.

(A) *Carapace.*—Composed of 51 bony plates, with the boundaries of the 38 horn shields all clearly marked as deep and distinct furrows.

(1) *Bony Plates:* Marginals 11 pairs, all united to pleurals by sutures; the 2d deeply round pitted posteriorly for reception of outer anterior limb of the hyoplastron: the 7th–11th of broadly oblong shape, slightly concave on upper surface, the inferior faces being more strongly convex; external borders forming a continuous outer curvature from the nuchal to the ninth, but borders of 9–11 and the pygal marginal slightly convex; 4th–6th very slightly escalloped on inner upper border and exposing rib tips a little; 7th–10th with deep V-shaped notch in inner upper border distinctly exposing the tips of the ribs; rib pits flattened: mar-

* Extinct Batrachia, Reptilia, and Aves of North America, Trans. Amer. Phil. Soc., vol. xiv, 1869, page 140.

ginal-costal furrow crosses the posterior corner of M1, inner ends of M2 and 3, nearly or wholly coincides with inner borders of M4–6 and crosses inner ends of M7–11; nuchal, large, sub-pentagonal, anterior border nearly without nether or costiform process, straight as viewed vertically; pygal marginal of medium size, notched anteriorly: pleurals, 8 pairs, all uniting by sutures with the marginals, with the distal ends as broad as, or broader than, the proximal ends, and the flat ribs projecting peg-like into pits in the marginals (gomphosis): neurals 9, the first 8 about twice as long as broad,—No. 1 with rounded ends, Nos. 2–7 notched anteriorly, rounded posteriorly, No. 8, elliptical, No. 9 broader than long. Anterior pygal assymmetrical,—large, uniting with inner border of 10th and 11th marginals; posterior pygal of sub-trapezoidal outline, broadest in front, and with double curve in posterior border for reception of the anteriorly notched pygal marginal. (The anterior and posterior pygal are represented by a single pygal in *Adocus*.)

(2) *Horn Shields.*—The boundaries of all the horn shields are delimited by uniform deep border grooving on the bony plates: nuchal shield wide; 11 paired marginals, with a

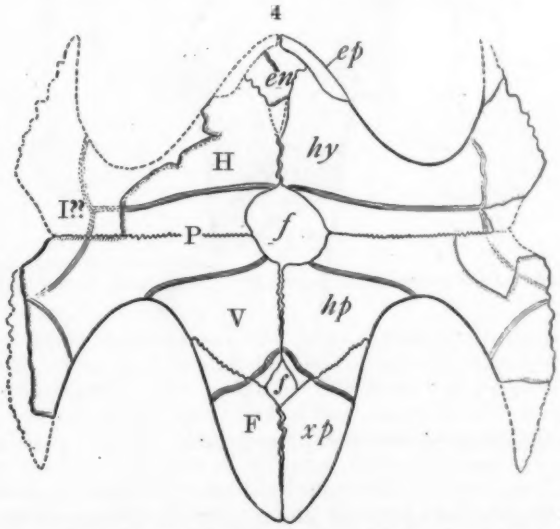

FIGURE 4.—*Osteopgis Gibbi* type. Exterior view of plastron showing horn-shield markings. × ½.

(1) Bone plates.—*Ep*, epiplastron; *en*, entoplastron; *hy*, hyoplastron; *hp*, hypoplastron; *xp*, xiphiplastron; *f*, *f*, foramina.

(2) Horn shields.—H, humeral; P, pectoral; V, ventral; F, femoral; I??, region of indistinct inframarginals.

twelfth or supracaudal pair, none of which overlap the ends of the pleuralia; the 4th–10th rising just to, or a little above the bottom of the marginal notch above noted as exposing the rib-tips: costals 4 pairs, large: vertebralia 5, the 1st–3d and 5th of normal pattern, the 4th of ornate outline like the vertical section of a wide-mouthed and small-bottomed jug.

(B) *The Plastron.*—Of much reduced size, the length being about $\frac{3}{5}$, and the least width of the bridge less than $\frac{1}{6}$ that of the carapace. Composed of 9 bony plates, with the furrows marking the horn shields rather indistinct, but evidently as shown in text figure 4.

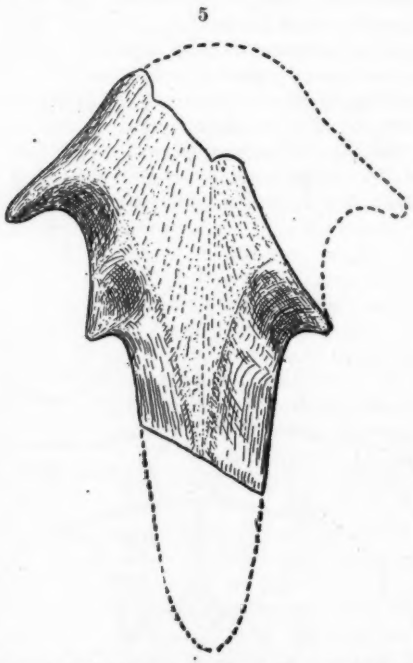

FIGURE 5.—*Osteopygis Gibbi* type. Entoplastron. Outer view, natural size.

(1) *Bony Plates.*—The general outline of the bony plates combines features of *Chelydra* and of the Dermatemydidæ. The narrow epiplastra meet at a rounded obtuse angle as in *Staurotypus*. The entoplastron, as shown in the accompanying text figure 5, exhibits a condition which is intermediate between that seen in a turtle like *Adocus*, and the reduced and rod-like condition in *Chelydra*. Union of the remaining elements on

the median line is by digitation—not by suture, with a large assymmetric and sub-oval median foramen at the hyo-hypoplastral, and a much smaller, at the hypo-xiphiplastral junction (*f*, *f*, figure 4). There are also small lateral foramina of crescentic outline between the 5th marginal and the hyo- and hypoplastron, as may be seen in Plate VIII.

The manner of the bridge connection with the carapace is of interest. Although truly dactylosternal, there are distinct suggestions of a former cleidosternal (closely interlocking suture) union as in *Adocus*. The axial and inguinal limbs or buttresses project into sockets in the posterior end of the 2d and the anterior end of the 8th marginals.

6

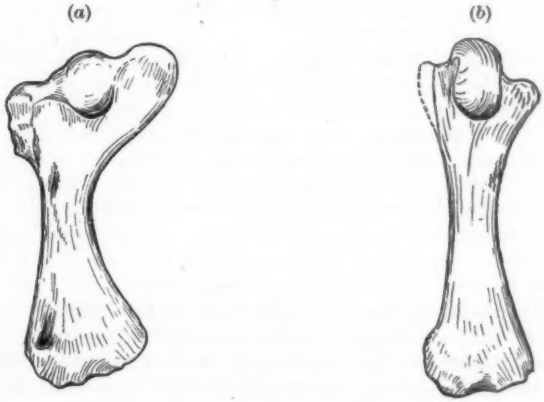

FIGURE 6.—*Osteopygis Gibbi* type. × ½.
(*a*) Left humerus, dorsal view.
(*b*) Right femur, dorsal view, with fibular trochanter shown in dotted outline.

Cope speaks several times of a large rib cavity in the second marginal. But such cannot be present in any species of the genus *Osteopygis*. *The second, or first large rib, projects with strong backward curvature into a long claw-like depression in the third marginal.* The large pit in the second marginal appears to be a remnant of a former hollow beneath the axial buttress, and must serve mainly for muscular attachment, since only the lower edge is occupied by the end of the hyoplastral peduncle. The dactylations between the buttresses are short and robust. Those of the hyoplastron project against the lower inner border of the 3d and 4th marginals, which are pitted for their reception. Those of the hypoplastron project similarly against the 6th and 7th marginals. The hypoplastral

limbs or peduncles however pass gradually beneath the posterior edge of the seventh, and end as mentioned, in the anterior pit of the eighth marginals.

(2) *Horn Shields.*—The boundaries of the plastral horn shields are not all distinct, and these being the only portions whatsoever of either carapace or plastron that are not entirely so, it has been deemed best to indicate them, so far as determined, separately in text figure 4. As there shown, the inframarginal region is not clear. The anterior border of the pectorals, ventrals and femorals is however distinct, anals not being present, or else diminutive as in *Chelydra*. The gular boundaries do not show clearly, but these elements were probably small as in the existing *Staurotypus Salvinii*, with which there is in the general arrangement, number and size of parts a fairly striking comparison.

(C) *Limb and Other Bones.*—The *humerus*, as shown in text figure 6*a*, is in part intermediate between what I have termed the chelic (*Chelydra*) and the *parachelic* (*Testudo*) form.* The proximal end approaches the Chelydran form very distinctly. It is very large and the shaft slender. But the distal end is facetted, and in this respect approaches the grooved character seen in some forms of *Testudo*. The ectepicondylar foramen is a deep perforation. The only well-marked suggestion of departure in the direction of marine forms is afforded by the obtuse angle between the radial and ulnar crest, this being markedly greater than in *Chelydra*.

The *femur*, as might well be surmised in *Osteopygis* from the oval outline of the carapace, is as in *Chelydra* distinctly larger than the humerus (see figure 6 *a* and *b* in text). The

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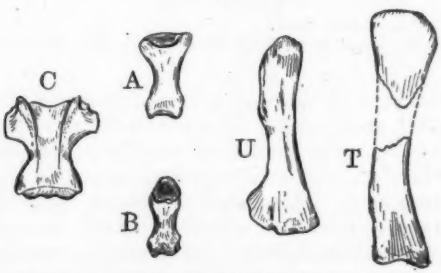

FIGURE 7.—*Osteopygis Gibbi* type. × ¼.
C, superior view of seventh cervical centrum; A, superior view of first, and B, of the second left Metatarsalia; U, outer view of left Ulna; T, outer view of right Tibia.

* Some Observations on Certain Well Marked Stages in the Evolution of the Testudinate Humerus, this Journal, vol. ix, 1900, 413–424. See also, L'Evolution des Chéloniens Marin par L. Dollo, Bull. Acad. Roy. Belgique Cl. Sc. (Aug. 9, 1903).

most distinctive feature is the continuation of the articular surface well out on to the fibular crest. The distal end, as in the humerus, is facetted, not smooth. The characters of the ulna and of the tibia, and the several phalanges present, are in the main quite comparable feature by feature with these several elements in *Chelydra* (see text figure 7).

Of great interest is the form of the limbs. It is not to be said off hand that *Osteopygis* had flippers, as is implied by placing the genus in the Chelonidæ, as has been done in the American edition of Zittel's Handbuch. The limb bones above made known are not entirely conclusive on this point. The best study of the evidence at hand may be made from the following tabular statement:—

	Chelydra.	Osteopygis.	Eretmochelys.
Length of shell	(26·)	74·	(37·)
" humerus.....	6·	14·5	8·
" femur.....	6·4	15·	6·
" ulna	3·5	8·	4·
" 1st metatarsal	1·1	3·4	1·4
Ratio to length of shell.			
humerus	4·3	5·1	4·6
femur	4·0	4·9	6·1
ulna.....	7·4	9·2	9·2
1st metatarsal	23·6	21·8	26·4

The larger the ratio the smaller the part, whence *Osteopygis Gibbi* has a relatively shorter femur, humerus and ulna, with a longer metatarsal than *Chelydra*. But the humerus is relatively shorter than that of *Eretmochelys*, the femur relatively much longer. Comparison of the metatarsal in *Eretmochelys* cannot however be readily made since the hind flipper of the latter is so very greatly reduced. The conclusion I am led to is that the present species had by no means so well developed flippers as I have shown the primitive sea turtle *Toxochelys** to have had. But as the phalanges had undergone some elongation the toes must at least have been strongly webbed though doubtless they yet retained their claws. The smooth distal end of the humerus of the closely related *Propleura* is considerably more like that of the marine or natatorial types, and may indicate that these forms were undergoing some adaptation of the limbs for a pelagic or a littoral habitat. It would however seem that the marine Chelonians destined to survive were those which early acquired relatively powerful humeri, and it is probable that a form with a long femur like *Osteopygis*, even if the feet were fairly developed as flippers, was

* Notes on the Cretaceous Turtles *Toxochelys* and *Archelon* with a classification of the Marine Testudinata. This Journal, vol. xiv, 1902, p. 95.

not so good a swimmer as any of the existing marine turtles. In any case it is very evident that *Osteopygis* and the following closely related *Propleura* are among the most interesting of all known forms on the border line between littoral and marine Chelonians.

The 7th cervical is coelo-bicyrtean, the double convexity of the posterior end not being very marked. It is very broad in front, mainly because of heavy somewhat downwardly directed transverse processes, and had a heavy median keel running along its full length. The base of the neural arch is rather slender. Regarding the skull of *Osteopygis* we are as yet uncertain. It may prove to be like that of the prior genus *Euclastes*, as was thought possible by Cope or has since been assumed on ground not known to me. This remains to be carefully proven or disproven.

Systematic Position.—The type of the genus *Osteopygis* is the species *O. emarginatus*, and the present species appears to be more nearly related to it than to any of the several subsequently described forms. The type specimen of *Osteopygis Gibbi* differs from *O. emarginatus* in having a convex (not slightly concave*) outer surface of the 1st marginal, and in the conformation of the horn shields of the posterior marginals, several being distinctly smaller. Also the marginals are not notched. The lack of figures, and the fragmentary condition of the type, prevent further comparison.

In the case of *Osteopygis platylomus*, which has well marked pleuro-marginal fontanelles, the differences are clear, and it is not entirely certain that this species falls within the genus *Osteopygis*, which as hitherto constituted is quite certainly too far extended.

There is no living form to which *Osteopygis* can be at all so nearly compared as can be *Adocus* to *Dermatemys*. But if the carapace only be considered, there is a certain resemblance to such forms as *Kachuga* and *Hardella* (Burma and Pegu). On the other hand, there is marked similarity between the plastron of *Osteopygis* and that of *Staurotypus* of Central America. Moreover the carapace of this latter genus presents certain features that seemingly could have been derived from some ancestral *Osteopygid* form by fusion of parts, especially in the pygal region. It is therefore with the existing Central American genus *Staurotypus* that we may best compare *Osteopygis*, the differences however being of full family value. It is also very interesting how the dorsal characters of such a pleurodiran as *Plesiochelys solodurensis* (Upper Jura, Kimmeridgian) are strikingly like those of *Osteopygis*, while the plastron is almost identically like that of *Adocus*.

* Proc. of the Phil. Acad., May 12, 1868, p. 147.

—As to the exact systematic position of the family to which *Osteopygis* (and *Propleura*) belong I feel abundantly justified in for the present withholding final judgment, but think it would seem best for the time being to retain these genera in Cope's Propleuridæ, and separate *Lytoloma* in another family, the Lytolomidæ.

Measurements of Osteopygis Gibbi.

(Skeletal parts uncrushed.)

(A) *The Carapace.*

Length on straight line	74·3cm
" over curvature (greatest)	69·0
Greatest width	58· ±
Projection beyond front end of plastron	9·4
" " hinder " "	22·4

(1) *Bony Plates of the Carapace.*

	Exact length on outer edge of Carapace.	Length from lower edge of Carapace to union with pleurals.
Nuchal	12·7cm	----
1st Marginal	7·9	6· cm
2d "	8·2	6·
3d "	7·5	6·1
4th "	7·6	6·
5th "	8·0	6·4
6th "	8·5	6·2
7th "	9·2	8·1
8th "	9·5	10·5
9th "	9·3	10·5
10th "	9·0	11·1
11th "	8·3	11·0
Median or Pygal Marginal	8·3	(7·1)

	Length.	Greatest width.
Nuchal	7·5	14·5
1st Neural	9·5	4·1
2d "	6·5	4·7
3d "	6·5	4·7
4th "	6·5	4·3
5th "	(5·)	3·7
6th "	(4·5)	3·3
7th "	(4·5)	3·0
8th "	(6.5)	(3·8)
9th "	(2.0)	(4·3)
Pygal (anterior)	6·	16·2
" (posterior)	6·	9·7
" marginal	7·1	8·3

	Length (laterally) over curvature along posterior sutural border.	Width across middle.
1st Pleural	21·0 cm	10· cm
2d "	25·0	7·5
3d "	28·0	7·0
4th "	27·0	6·8
5th "	22·0	6·5
6th "	19·0	5·0
7th "	16·0	5·4
8th "	9·0	5·5

(2) *Carapacial Horn Shields.*

Extreme width of Nuchal ..... 9·0 cm

Length of 1st–11th Marginalia, respectively, along outer edge of carapace:—
5·4, 8·0, 8·1, 8·5, 7·3, 8·5, 9·5, 9·7, 9·7, 9·5, 8·0, 8·4 cm

Greatest lateral length of 1st–4th Costalia, respectively, 21·0, 25·0, 22·0, 16·0 cm

Greatest antero posterior length 1st–5th Vertebralia, respectively, 11·0, 14·0, 13·5, 14·0, 14·5 cm.

(B) *The Plastron.*

(Shields, Bony Plates.)

Length	43·0 cm
Width, greatest	48·
Distance between axial and inguinal buttresses	38·5
Length of Epiplastron	9· ±
Width of Entoplastron	5·9
Least width across the hyo- and hypoplastral bridge	11·4
Greatest length of Xiphiplaston	18·5
" width of "	5·5

(C) *Other Skeletal Parts.*

(1) The *Humerus.*

Extreme length	15·1 cm
Distance from outer border of radial to end of ulnar crest	7·5
Diameter of head (dorso-ventral)	3·0
Dorso-ventral thickness of middle of shaft	1·8
Greatest distal width	5·2
Distance of ectepicondylar foramen from anterior border	·8

(2) *Femur.*

Extreme length	15·1
Antero-posterior diameter of head	2·3
" " " of middle of shaft	1·85
Greatest or antero-posterior distal width	4·5
(3) Greatest length of ulna	8·3
(4) " " of 1st metatarsal	3·4
(5) " " of 2d "	3·1
(6) " " of 7th cervical centrum	3·8

(D) *Thickness of Certain Bones of Carapace.*

Nuchal on median line	1·6^{cm}
" at ends	1·7
2d Marginal at anterior end	2·1
8th " " border	2·6
8th " posterior "	1·4
9th " " "	1·4
Thickness 3d Marginal near inner border	0·6
7th Pleural at distal end	0·6

III. *Propleura Borealis* sp. nov.—(Plate IX.)

A new species belonging to a different genus from *Osteopygis*, but to the same family, the Propleuridae of Cope, is indicated by Yale Specimen No. 778, from the old Cream Ridge Marl Company's Pits, near Hornerstown, Monmouth Co., New Jersey. This fine Upper Cretaceous turtle was received at the Yale Museum in May, 1870. It consists in the nuchal; 1st and 2d neuralia; the 2d, 3rd, 5th, 6th and 7th right, and the 1st, 2d, 3rd, 5th and 6th left marginalia; the 1st and 2d, the 4th and 5th right pleuralia, with the 1st and 2d left pleuralia; the hyoplastron and hypoplastron of the right side, with both xiphiplastra; the left humerus, the pubis and ilium of the left side, and both ischia. None of these bones are crushed, and they are mostly little or not at all broken, and in a fine state of preservation, as may be seen by reference to Plate IX, where a photograph of all is given, the elements of the Carapace being placed in their approximately natural position, with the grooves marking the boundaries of the horn shields marked in ivory black water color. The portions of the plastron present are but very little broken, the view given being ventral, just as if the parts were brought out from their natural position beneath the carapace and to one side. Note that the anteroexterior limb of the plastron so often broken away in dactylosternal fossil plastra is entire. It projected into a pit at the posterior end of the second marginal, in the manner also seen in *Osteopygis*, and the interesting form of dactylate plastral union described above for that genus is also repeated in the present turtle. The humerus was broken in two, but the edges of the fracture unite solidly.

The pelvic elements unfortunately have their median symphysial borders broken away, but so much is present as to abundantly warrant their restoration, as shown laid flat and seen from the ventral side on Plate IX.

Description and Comparison with Osteopygis.

The form before us I shall, reviving Cope's genus, call *Propleura borealis.** The specific name may serve to lay

* Extinct Batrachia, Reptilia, and Aves of North America. Trans. Amer. Phil. Soc., vol. xiv, 1869, pages 138 et seq.

stress upon the fact that the nearest relatives of this turtle and its congeners are, so far as yet present in existing faunas, now mainly to be found in far southern lands. The species is next related to *Propleura* (Osteopygis) *erosa* of Cope, and to the type of the genus *Propleura* (Osteopygis) *sopita* as further noted below.

The arrangement of the plates and horn shields approaches that of *Osteopygis*, but there are many differences, the citation of which following the notes already made on this genus will answer quite fully the purposes of description. The differences follow:—

(*a*) The surface of the bones of the Carapace is not smooth to fine lined, as in *Osteopygis*, but coarsely round pitted to uneven depths, as if by numerous rain drop impressions of different sizes. Comparison of the surface of the various parts of the skeleton shows that while there are pittings present that may be ascribed to accidents of preservation, the characteristic pitting of the Carapace as shown in the plate is a true surface sculpturing. The pits are from 1 to 6^{mm} across, and from 1 to 3 or 4^{mm} deep, the average size being about 3^{mm} in diameter by 2^{mm} in depth.

(*b*) The proportion of the carapacial parts is quite different from that seen in *Osteopygis*. The nuchal has much more anterior concave curvature than in *O. Gibbi*, and though scarcely broader or longer, is nearly twice as thick. Contrariwise, the relatively much heavier second marginals are longer.

(*c*) The external border of the 6th and 7th marginals is notched at the boundary line of the horn shields, not unbroken as in *O. Gibbi*.

(*d*) The interior borders of the marginals present, following the anterior two-thirds of the second, which like all that of the first unites with the 1st pleural by suture, are smooth. Also the outer corners of the rib plates following the first end in oblique smooth edges, thus forming a series of well marked lateral or pleuro-marginal fontanelles, which lie opposite the marginal junctions beginning with the 2d and 3d, and likely extending to the 9th and 10th. These are of broad crescentic outline, and the one bounded by the 6th and 7th marginals and the 4th and 5th pleurals is 7^{cm} long and about half as wide. See Plate IX. There are no pleuro-marginal fontanelles in the distinctly smaller turtle *Osteopygis Gibbi*, and probably none in any specimen justly referable to the genus. Such fontanelles formed at the outer edges of the pleuralia constitute an anatomical feature that is quite different from the marginal notch over the 3d–9th rib tips as in *Osteopygis*.

(*e*) The rib pits are of rounded conical shape, and not flattened.

(*f*) The humerus of specimen 778 has much more rugose radial and ulnar crests than that of *Osteopygis*. Also corresponding well with the presence of pleuro-marginal fontanelles, the distal end is well rounded like that of *Chelydra*. The general form is chelic to chelicoid. The angle between the proximal crests is much more obtuse than in any of the Chelydridæ, and the ectepicondylar foramen is well enclosed. This latter is a retained primitive position.

The Pelvis.—The pelvis of the type just described is fortunately present as mentioned above, and can only be given separate description, since this portion of the skeleton of *Osteopygis* and allied forms has not hitherto been known. Although the median symphysial borders of both the pubes and ischia are broken away, the remainder of the pelvic outline is quite entire, and has warranted the restoration shown in Plate IX. There the parts are shown laid out flatwise and as seen from their lower, that is, from the acetabular side. The general structure and outline of parts is much like that seen in *Chelydra*, except that the distal articular surface of the pubis is much longer as in the marine turtle *Toxochelys*, which also has a somewhat Chelydra-like pelvis.

It is to be noted that the preceding facts and comparisons indicate a turtle close to *Propleura* (Osteopygis) *erosa* Cope, the type of which has not been figured. Cope says the species *O. erosus* has vertebral bones more than twice as long as wide, which *is not the case* in the 1st and 2d vertebrals, the only ones preserved, in the turtle before us. Completer knowledge of the two species may, however, show their identity. From *Propleura* (Osteopygis) *sopita* separation is based on the different proportions of the marginals, though in most other respects there is close agreement so far as may be adjudged from the fragmentary type material described and figured.* But generic separation of these specimens from *Osteopygis* must hold as based on the presence of well-marked lateral pleuro-marginal fontanelles, conical rib pits of the marginals, and humeri with smooth not sculptured distal ends.

Measurements of Propleura borealis.

Greatest width of Carapace	65·6^{cm}
Length of Marginals measured along the outer edge:	
1st Marginal	10·0
2d "	9·5
3d "	7·5
4th "	
5th "	9·0
6th "	10·4
7th "	11·0

* Extinct Batrachia, Reptilia and Aves, Plate VII.

Length over curvature measured along posterior sutural borders.	
1st Pleural	21·0 cm
(2d ")	23·0
3d "	25·0
4th "	24·0
5th "	21·0
Width of Nuchal measured along anterior border	14·0
Greatest width of Nuchal	18·5
Anterior posterior length of Nuchal	9·0
Anterior-posterior length of first Neural	10·2
Greatest width 1st Neural	5·5
Greatest width 2d Neural	5·7

The Plastron.

Greatest lateral width of the hyoplastron	25·0
" " " hypoplastron	17·0
Length along median line of interdigition of Xiphiplastra	11·0

The Pelvis.

Distance from lower outer border of acetabular surface to base of the ento-ectopubic notch (or curve)	6·2
Distance from acetabulum to base of inner post ischial curve	5·5
Least distance from center of acetabulum to extremity of ilium (or surface of iliac support on carapace)	8·0

The Humerus.

(Normal in every respect.)

Extreme length	17·0
Distance from outer border of radial to end of ulnar crest	7·8
Diameter of head (dorso-ventral)	3·25
Dorso-ventral thickness of shaft	1·7
Greatest distal width	5·4
Distance of entepicondylar foramen from anterior border	1·1

Paleontological Laboratory,
Yale University Museum,
New Haven, Conn.

ART. X.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN.

[Continued from vol. xvii, p. 33.]

Omomys pucillus Marsh.

Hemiacodon pucillus Marsh, this Journal, 1872, p. 22, Separata.

The type of this species, figure 124, consists of a fragment of a right mandibular ramus bearing the second molar, the structure of which agrees very closely with that of the corresponding tooth of *O. Carteri*, but the former is distinctly smaller. A second jaw fragment in which the second and third molars are preserved undoubtedly belongs to the same species. In my own collection, there are two jaw fragments in association with two superior molars, and in the Marsh collection there is one entire series of superior molars. These additional specimens, figures 125 and 126, furnish as complete a knowledge of the dentition as that described in the foregoing species. The dental formula of the lower jaw is the same as in *O. Carteri*, and with some few exceptions, which are of no more than specific importance, the details of structure are very similar. The chief distinctions separating *O. pucillus* from *O. Carteri* are the following: The species is considerably smaller; the last lower molar is slightly more reduced,

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FIGURE 124.—Jaw fragment containing the lower molar of the right side of *Omomys pucillus* Marsh (type of *Hemiacodon pucillus* Marsh); side and crown views; a little more than four times natural size.

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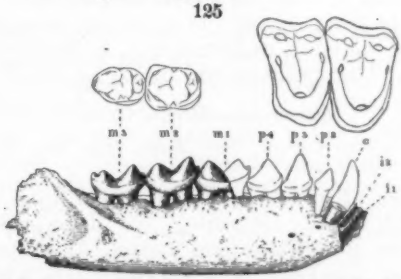


FIGURE 125.—Lower jaw and two superior molars of *Omomys pucillus* Marsh; side view of lower jaw, with side and crown views of teeth, and crown view of superior molars; the last are represented in outline five times natural size, while the lower jaw is a little less than three times natural size, and is drawn from three specimens.

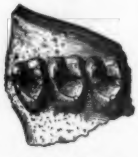
and there is a distinct ridge descending from the external cusp of the heel into the valley—a structure which is wanting in *O. Carteri;* the crown of the last upper molar is not so pointed internally; the postero-internal cusp is better developed upon the second than on the first molar; the intermediates are a little less distinct than in *O. Carteri.*

The species is thus far known from the lower and middle horizons of the Bridger.

Omomys Ameghini sp. nov.

A third still smaller species, which I refer provisionally to this genus, is represented by a fragment of a lower jaw of the left side, containing the second and third molars, figure 127. Besides being smaller in size than that of *O. pucillus*, the trigon is elevated above the heel to a much greater extent. This gives a somewhat insectivorous appearance to the teeth, but they are otherwise as in the species of *Omomys.*

126



127

FIGURE 126.—Crown view of three superior molars of the right side of *Omomys pucillus* Marsh; two and one-half times natural size.

FIGURE 127.—Jaw fragment of the left side of *Omomys Ameghini* Wortman; side and crown views; two and one-half times natural size. (Type.)

The last molar is little reduced, and the anterior cusp of the trigon is distinct in both the second and third.

The locality from which the specimen was obtained is not mentioned on the label, unfortunately, so that its exact horizon is unknown. The specimen was found by Mr. J. W. Chew.

Omomys uintensis Osborn.

Microsyops uintensis Osborn, Bull. Amer. Mus. Nat. Hist., 1895, p. 77; ibid., June 28, 1902, p. 202.

This species of *Omomys* was founded upon a fragment of jaw from the Uinta, containing the third and fourth premolars and the first and second molars. The specimen is preserved in the American Museum collection, and has recently been figured by Osborn in his paper on the American Eocene Primates. At the time of its description, Osborn referred the specimen to the genus *Microsyops*, but in his last paper that reference is considered erroneous. After a careful examination of the type and a detailed comparison with *Omomys*, I am fully convinced that it is the Uinta representative of this

genus, and is therefore the only Primate thus far known from the Uppermost Eocene of North America.

Its relationship is at once seen in the elevated character of the crown of the third premolar, as well as in the general agreement in the structure of the teeth. It is, however, the largest species of the genus known, and exhibits a marked advance in the structure of the teeth, in the more widely separated and distinct condition of the internal cusp of the fourth premolar, as well as in the absence of the anterior cusp of the trigon on the second molar. The Bridger species are all smaller and more primitive.

Hemiacodon gracilis Marsh.

Hemiacodon gracilis Marsh, this Journal, September, 1872, Separata, August 13, 1872, p. 21; *Omomys gracilis* Osborn, American Eocene Primates, Bull. Amer. Mus. Nat. Hist., June, 1902, p. 173.

This is one of the most abundant species of monkey in the Bridger formation, and as far as the specimens show is confined to the upper levels of the horizon. The type upon

128

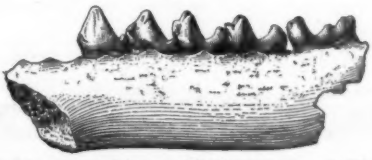


FIGURE 128.—Portion of right mandibular ramus of *Hemiacodon gracilis* Marsh; inside view; two and one-half times natural size. (Type of the genus and species.)

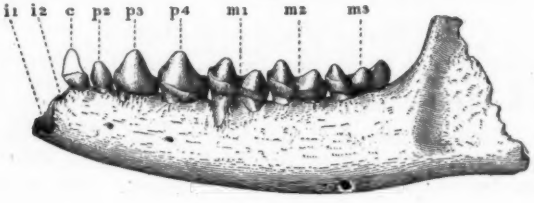
The elevation of the summit of the crown of the third premolar is greater in the type than in other specimens, on account of being partially out of the socket.

which Professor Marsh established the genus and species consists of a considerable part of a right mandibular ramus, figure 128, bearing the third and fourth premolars and the three molars in excellent preservation. The specimen also exhibits the alveoli for the second premolar, canine, and the two incisors, but is not sufficiently complete in front to admit of a determination of the number of incisors beyond all question. As compared with *Omomys Carteri*, the teeth of the lower jaw display in their structure a striking similarity to those of this species, and it is not at all surprising that Professor Marsh should have referred the two to the same genus. The chief differences consist in the enlargement of the first incisor and the reduced condition of the second incisor, canine, and second premolar, as well as in the better development of the internal cusp of the fourth premolar in *Hemiacodon gracilis*. The relations of the teeth in the front part of the jaw, I regard as

of more than specific importance, and these constitute in my estimation the main characters upon which the generic distinction rests.

In the molars the anterior cusp of the trigon is distinct in all, but least so in the last. There is likewise a very faint indication of a posterior median cusp in the heel of the first and second molars in the type, but in other specimens it is apparently absent. The posterior portion of the crown does not widen so rapidly as is the case in *Omomys Carteri*, the

129



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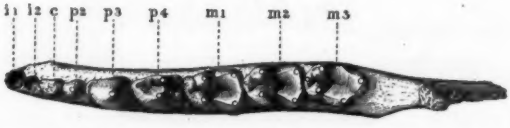

FIGURE 129.—Left lower jaw of *Hemiacodon gracilis* Marsh; external view; two and one-half times natural size; drawn from two specimens.

FIGURE 130.—Crown view of the same specimen.

In the drawing the alveolus of the first incisor does not appear as large as it actually is. The upper portion of the alveolus is broken away, so that only the bottom of the cavity is shown.

transverse diameter of the anterior and posterior moieties being more nearly equal. The fourth premolar is more advanced in structure than the corresponding tooth of *O. Carteri*. The third premolar in the type shows no trace of an internal cusp, but in some other specimens in the collection, of which forty or fifty individuals are represented, there is a distinct rudiment of this structure to be seen.

The second premolar and canine, figures 129 and 130, are preserved in several specimens, and their reduced size, as compared with the third premolar and the corresponding teeth of *O. Carteri*, is very evident. The incisors are not preserved in any specimen in the collection, but in several the front part of the jaw is sufficiently complete and well preserved to permit the alveoli to be made out with certainty. From these the number is shown to be two, of which the first is considerably larger than the second. The teeth were implanted in an uninterrupted

series and there is good evidence that the incisors were not very procumbent in position. The two halves of the lower jaw were not coössified, even in the most aged individuals.

In the upper jaw, figure 131, the teeth occur, in many examples, in association with those of the lower series. The structure of the molars is distinctive, not only by reason of the rather sharply quadrate outline of their crowns, but also because of their relatively great transverse extension. The first and second are subequal in size, and the third is considerably

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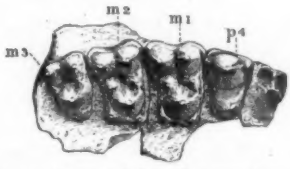

FIGURE 131.—Superior molars and fourth premolar of *Hemiacodon gracilis* Marsh; crown view; two and one-half times natural size.

The representation of the forward extension of the internal cingulum of the molars, as well as the size of the internal cingular cusp, is somewhat exaggerated.

reduced. The external cusps are moderately flattened upon their outer side, especially the posterior one, and they are bordered externally by a strong basal cingulum. The intermediates are unusually well developed, and there is a large internal pyramidal cusp. A small postero-internal cusp is developed from the cingulum, which continues forward around the inner side of the crown, and gives rise to a moderately strong subsidiary internal cusp. The extent to which this cusp, as well as the forward extension of the cingulum, is developed, however, appears to vary in the different specimens; in some the cusp is very distinct, while in others it is scarcely visible. The fourth premolar has single external and internal cusps. The third and fourth premolars are implanted by three roots, two external and one internal. The teeth anterior to these are unknown with certainty. The enamel is finely rugose in both the upper and the lower teeth.

In the fragment of a maxillary here figured, the anterior limits of the malar can be easily made out. It is thus shown that it does not reach forward to the lachrymal, but leaves the maxillary a considerable share in the anterior boundary of the orbit, as in the monkeys. The rather small, single, infraorbital foramen is situated above and opposite the posterior edge of the third premolar, about in the same relative position as that of the squirrel monkey. The maxillary gives further evidence of proportionally large orbits, and if the superior dental formula was the same as that for the lower jaw, the muzzle must have been considerably abbreviated. The whole aspect is, in

fact, not only characteristically Primate, but one considerably advanced.

In one specimen the head of a humerus is associated with a fragment of a lower jaw, which is apparently the proper size for *Hemiacodon gracilis*. The character of this bone is distinctly Primate. Among the living forms, it bears a closer resemblance to the humerus of *Propithecus* and *Avahis* than to any other with which I have compared it. This is particularly evident in the relatively great development of the lesser tuberosity and its inward and backward projection from the articular head. In this respect it also resembles the humerus of *Tarsius*, *Hapale*, and *Cebus*, although not so closely as it does that of the genera above mentioned. The large size of the lesser tuberosity is likewise a conspicuous feature of the humerus of *Limnotherium*, from which it may be concluded that it is a primitive character.

Professor Marsh has given the following measurements of the type:

Longitudinal extent of the nine lower teeth	20·5 mm
Extent of premolar and molar series	17·2
Extent of true molars	11·0
Antero-posterior diameter of last lower molar	4·0
Transverse diameter of last lower molar	2·4
Depth of jaw below last lower molar	6·3

The type specimen was found near Henry's Fork, by Mr. G. G. Lobdell, Jr. The other specimens of the collection are from the same horizon.

Hemiacodon pygmæus sp. nov.

A second species of this genus is indicated by a single superior molar, figure 132. Under ordinary circumstances, I should deprecate the proposal of a new specific name upon such an incomplete specimen, but in the present instance the relationship is so clearly indicated and the differences are so patent, that I do not hesitate to follow this otherwise reprehensible practice.

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FIGURE 132.—Superior molar of *Hemiacodon pygmæus* Wortman; crown view; four and one-third times natural size. (Type.)

The tooth in question displays its undoubted affinities with the molars of *Hemiacodon gracilis*, in its quadrate outline, its relatively great transverse extension, and the general arrangement of the cusps. The external cusps are somewhat more conical than those of *H. gracilis*, but the intermediate and internal cusps are practically the same as in that species. The great difference is seen in the size, *H. pygmæus* being but little more than one-half as large as *H.*

gracilis. It is possible that the tooth pertains to the small species described as *Omomys Ameghini*, but I do not think it likely.

The locality is not clearly indicated on the label, but the specimen was associated with other fragments from Dry Creek, which gives it an upper middle position in the Bridger horizon.

Euryacodon lepidus Marsh.

Euryacodon lepidus Marsh, this Journal, August and September, 1872, p. 33, Separata.

Professor Marsh in describing this genus and species says: "A small mammal, doubtless an insectivore, is represented by a fragment of an upper jaw containing the last two molars in perfect condition. Our collections contain other characteristic fossils which appear to be specifically identical with this specimen. The teeth preserved agree nearly in the composition of their crowns with the molars described by Dr. Leidy under the name *Palæacodon verus*, but each has its inner margin produced into a small tubercle. In the penultimate upper molar, this tubercle is especially prominent. The outer margin, also, of these molars has but a single faint indentation between the external cusps. Both teeth are surrounded by a distinct basal ridge. The specimens preserved indicate an animal about as large as a weasel."

Besides the type, there are in the collection four other examples which I refer to this species. One of these is a fragment of an upper jaw bearing the second and third molars, just as in the type; and three lower jaw fragments, which, however, in no instance are associated with the upper molars. The reference of the latter to this species, therefore, contains an element of uncertainty.

The upper molars, figure 133, resemble those of *Omomys Carteri*. In the second molar of this latter species, however, figure 123, the anterior internal cingular cusp is not developed, while in *Euryacodon lepidus* it is strong. The last molar, moreover, in the latter species is a little less reduced and the crown is not so narrow and pointed, especially on its internal or lingual side. The external cusps are rather conical, and the intermediates are moderately well developed. The homologue of the main postero-internal cusp has a somewhat more external position, and this portion of the crown has a distinctly less rectangular outline than the corresponding tooth in *Omomys Carteri*.

In the lower jaw, figure 134 (if the specimens are correctly referred to this species), the molars only are known. The structure of their crowns is quite different from that of any species of *Omomys*. The anterior cusp of the trigon is well

developed in the first molar, and has nearly the same relations as in the corresponding tooth of *Omomys Carteri*. In the second molar, however, this cusp has a much more posterior position and is decidedly smaller, while in the third it is completely absent. The last molar is narrower and more reduced than in *Omomys*, and the heel lacks the distinct pointed cusps seen in all the species of that genus. The crowns of the upper molars, especially that of the second, are almost as wide in front as behind, being in marked contrast with the molar

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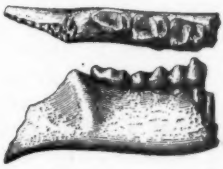

FIGURE 133.—Two superior molars of *Euryacodon lepidus* Marsh; crown view; a little less than four times natural size. (Type of genus and species.)
FIGURE 134.—Lower jaw fragment of *Euryacodon lepidus* Marsh; side and crown views; two and one-half times natural size.

crowns of the species of *Omomys*. Thus it will be seen that the lower molars of *Euryacodon* are more advanced than those of *Omomys*, and there can be apparently very little doubt that they represent distinct genera.

The complete dentition of the lower jaw is unknown, and I have provisionally referred the genus to the Omomyinæ. A comparison with the type of Cope's *Anaptomorphus æmulus*, from the lower horizon of the Bridger beds, shows many points of similarity. As is well known, the type of this latter species consists of a lower jaw in which the first and second molars are present, but the third is missing from the specimen. In *Anaptomorphus* the anterior cusp of the trigon has disappeared in both the first and second molars, which at once establishes the fact that it is at least a different species from *Euryacodon lepidus* and the most advanced form of Primate thus far known from the American Eocene. It is upon this account that I have chosen to regard *Euryacodon* and *Anaptomorphus* as distinct from each other, until the full dentition of the former and the upper teeth of the latter are more fully known. If *Euryacodon* is eventually found to possess only two premolars in the lower jaw, it will then probably be necessary to unite the two genera under the name *Euryacodon*, since the latter has distinct priority over *Anaptomorphus*.

[To be continued.]

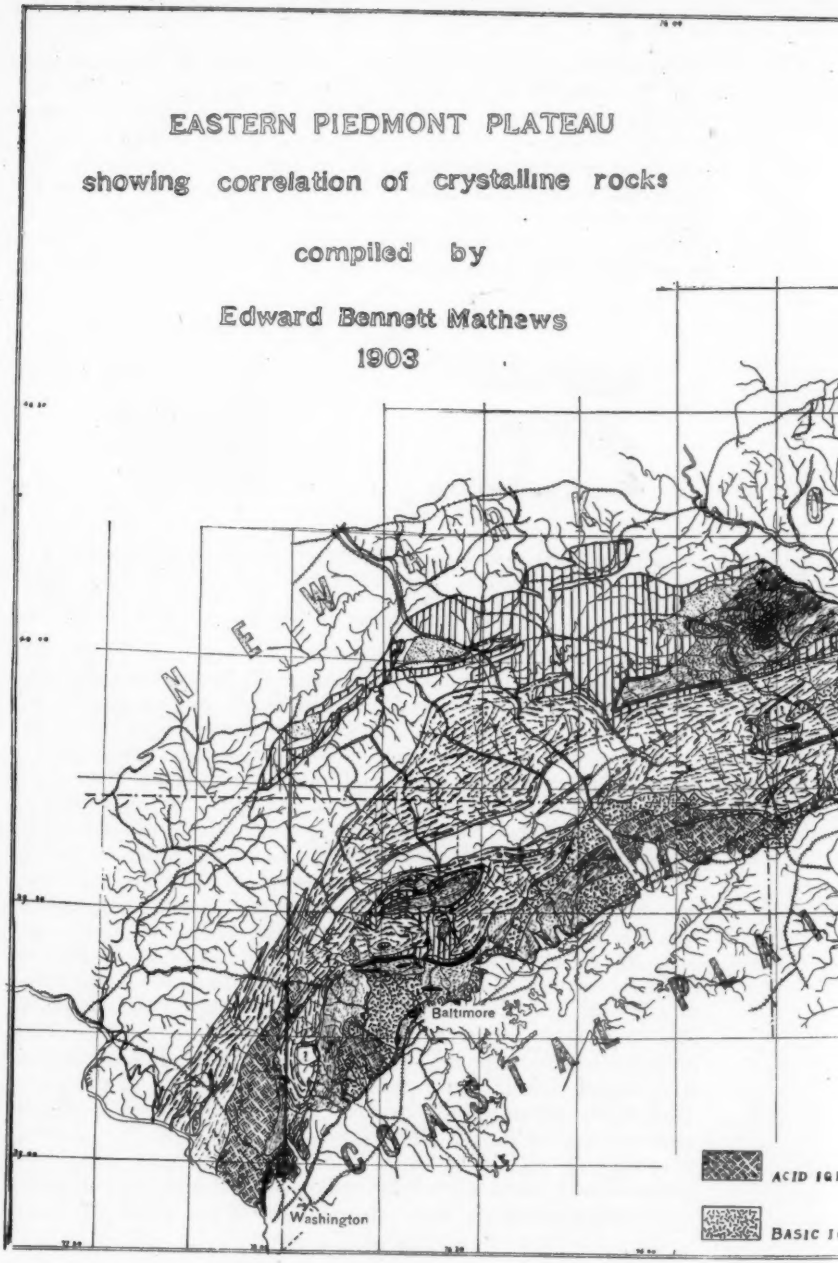
EASTERN PIEDMONT PLATEAU
showing correlation of crystalline rocks
compiled by
Edward Bennett Mathews
1903
NEWARK
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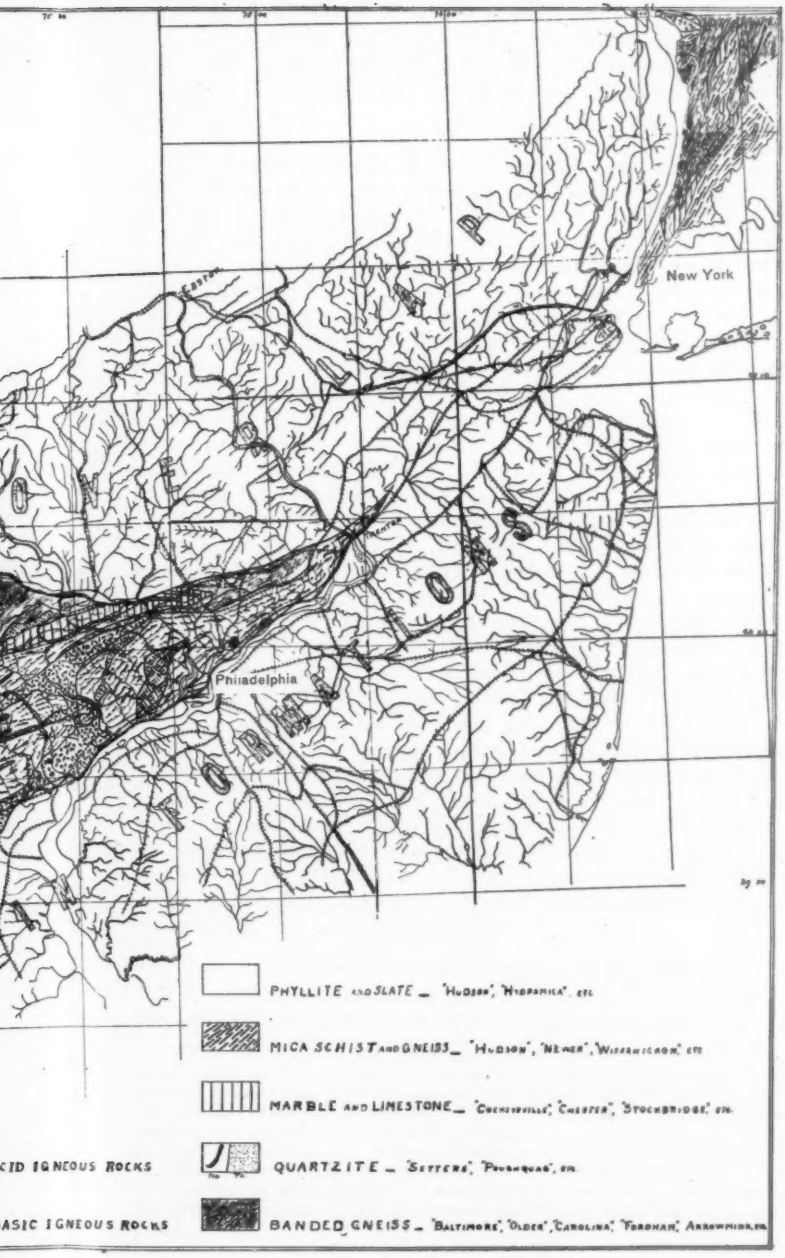
Plate X.


New York
Philadelphia
PHYLLITE AND SLATE — "HUDSON", "HYDRONICA", ETC.
MICA SCHIST AND GNEISS — "HUDSON", "NEMER", "WISSAHICKON", ETC.
MARBLE AND LIMESTONE — "COCKEYSVILLE", "CHESTER", "STOCKBRIDGE", ETC.
QUARTZITE — "SETTERS", "POUNDRIDGE", ETC.
BANDED GNEISS — "BALTIMORE", "OLDER", "CAROLINA", "FORDHAM", ARROWHEAD, ETC.
CID IGNEOUS ROCKS
ASIC IGNEOUS ROCKS

ART. XI. — *The Structure of the Piedmont Plateau as shown in Maryland;* by EDWARD BENNETT MATHEWS. (With Plate X.)

THE structure of the more or less metamorphosed sedimentary and igneous rocks exposed in the Piedmont Plateau, lying between the Blue Ridge on the west and the Coastal Plain on the east along the Middle Atlantic coast from New York southward, is a geological problem of wide interest to American geologists and has occasioned more or less discussion among various investigators who have worked upon it.

Throughout the Piedmont region are exposed numerous highly-crystalline gneisses and schists intermingled with crystalline limestones, quartzites, and phyllites which have been intruded by large and small igneous masses of granite, gabbro, serpentine, and volcanic rocks; all of which have been metamorphosed in varying degree up to the point where they have lost all evidence of their original condition.

The deciphering of the various formations occurring within the Piedmont is still in progress and many areas are yet unstudied, but the areal distribution of the various formations throughout the region north of Virginia has been determined with sufficient accuracy to indicate the various types of rock present. The areas about Washington, Philadelphia, and a large portion of the intervening country within the limits of the State of Maryland, have been studied in detail until it seems that some clue has been gained regarding the broad structural features and geological relationship of this complicated region. In the present paper it is proposed to give a tentative interpretation of the broader structural features as shown in Maryland by the detailed mapping of the author and his assistants during the last seven years. The basis of work* includes a reconnaissance of the entire Maryland Piedmont and the detailed mapping of approximately 1250 square miles lying north and east of Baltimore.

General Characteristics of the Piedmont.

The crystalline rocks of the Piedmont Plateau are well exposed in the area about New York, where they have been

* While the work in Maryland has been in progress, the author has had many office and field conferences with Dr. Bascom, who has generously allowed him to examine and to use her detailed manuscript maps of the Philadelphia area. The work in Maryland has been conducted independently at the same time and both investigators have been led to similar results for their special regions. The application of their common interpretation to the whole area of the Eastern Piedmont is here first issued by the author, who wishes to acknowledge the assistance received from his knowledge of Dr. Bascom's results which have most generously been placed at his disposal.

studied by Dr. F. J. H. Merrill* and his colleagues. Southward from the New York area the older crystalline rocks of the Piedmont are covered by the formations of the Jura-trias and do not appear again until in the vicinity of Trenton, whence they pass southwestward across Pennsylvania into Maryland, offering numerous good exposures along the banks of the Delaware, Schuylkill, and Brandywine, where they have been investigated by members of the Pennsylvania Survey and more recently in great detail by Dr. Bascom. Within the limits of Maryland the Piedmont crystallines are trenched by the Susquehanna, Gunpowder, Patapsco, Patuxent, and Potomac rivers and their tributaries. Beyond the Potomac, the same formations are continued southward through Virginia, North and South Carolina, Georgia and Alabama, where they have been examined by members of the different State surveys and by Mr. Arthur Keith of the U. S. Geological Survey.

In each of the areas studied, about New York, Philadelphia, Baltimore, and Washington, similar series of rocks have been found but the interpretation of their relationship has varied somewhat, and until recently no attempt has been made to determine the structure of the territory. The following table represents the lithologic types recognized in the different regions by the various authors.

From the following table it is easily seen that four distinct types of rocks have been recognized in each of the areas, though not always represented on the maps accompanying the verbal description. These are (1) a banded gneiss, (2) a thin-bedded or arkosic quartzite, (3) a marble, and (4) a series of mica schists.

Banded Gneiss.—In each of the areas is a highly crystalline gneiss composed of quartz, feldspar and mica with accessory minerals so distributed as to produce a well-marked gray banded gneiss, the individual bands of which vary from a fraction of an inch upward, the average thickness, however, being quite small. Some of these beds are highly quartzose resembling a micaceous quartzite, others are rich in biotite or hornblende producing dark to black bands indistinguishable in a hand specimen from mica and hornblende schists and gneisses derived from igneous rocks by metamorphism. Through these banded gneisses are intruded pegmatite and aplitic dikes more or less parallel to the regular banding of the gneiss. In all of the areas these beds are found highly inclined in their banding, which represents original variation in composition of the sediments or the igneous rocks from which they were formed. Some authors have regarded these as sedimentary, some as

*N. Y. Folio, Geologic Atlas of the United States, Folio No. 83, Washington, 1902.

TABLE SHOWING CORRELATION OF CRYSTALLINES IN EASTERN PIEDMONT.

Red sandstones and shales of the Jura-trias on the west and unconsolidated Coastal Plain Deposits of Jurassic-Recent age on the east; separated from the underlying rocks by a marked unconformity.

	New York area.	Philadelphia area.	Maryland area.		Washington area.
	Merrill.	Dr. Bascom.*	Williams.	Mathews.	Keith.
Silurian	Hudson schist, mica schist with garnet, staurolite, fibrolite, cyanite	Hudson mica schist and Wissahickon mica gneiss	Peach bottom slates Phyllite mica-schist muscovite-gneiss (in part)	Peach bottom slates Cardiff quartz conglomerate. Wissahickon mica schist including phyllite member at top	
Cambro-Ordovician	Stockbridge limestone.	Chester Valley limestone	Dolomite or marble	Cockeyville marble	
Cambrian	Poughquag quartzite, thin-bedded white to brownish carrying tourmaline and muscovite	Valley Forge and Edge Hill quartzite	Setters quartzite	Setters quartzite	
Pre-Cambrian	Fordham gneiss, gray banded, potash, feldspar, quartz, mica, hornblende	Arrowmink arkosic gneiss	Biotite gneiss muscovite gneiss (in part)	Baltimore gneiss	Carolina gneiss (in part)

* Dr. Bascom has furnished the following correlation of formations as recognized by different investigators in the Philadelphia area:

Rogers.	*Hall.*	*Bascom.*
Talcose and micaceous slate (middle member of Primal series)	Quartzose slate and mica schists (Rand's hydromica schists)	Hudson mica schists and
First and second gneissic belts	Chestnut Hill garnetiferous schists Manayunk mica-schists Philadelphia schists and gneisses (in part)	Wissahickon mica-gneiss (Hudson age)
Auroral limestone	Limestone, No. II	Chester Valley limestone (Cambro-Ordovician age)
Primal sandstone	Potsdam, No. I	Valley Forge and Edge Hill quartzite (Lower Cambrian)
Third gneiss belt	Eozoic or Azoic or Laurentian gneiss (in part)	Arrowmink arkosic gneiss (Pre-Cambrian)

This is exclusive of igneous material. The Overbrook porphyritic granite-gneiss is included in Hall's Philadelphia gneisses and the great gabbro intrusive forms a large part of the Laurentian gneiss (so-called) which also includes some of the Wissahickon mica-gneiss (Frazer).

igneous, some as sedimentary masses intruded by igneous rock to form so-called injection gneisses. All have agreed that these banded gneisses are probably pre-Cambrian in age whatever their origin. Usually in eastern Maryland they are separated from other metamorphosed sedimentary rocks by igneous masses, but in the vicinity of Baltimore and in the Philadelphia area, as shown by Dr. Bascom, these banded gneisses immediately underlie the quartzite.

The Quartzite.—The quartzite is a fine-grained, somewhat saccharoidal, thin-bedded quartzite of white-brown color. The beds are usually separated by thin films of muscovite in small sparkling flakes. On the surface of these mica-covered cleavage or bedding planes frequently occur black tourmaline crystals which occasionally show evidence of movement along these planes. Individual specimens of the quartzite when massive may appear like the quartzose layers of the banded gneiss, but usually the rock is easily distinguished in the field. It generally is found dipping at a rather steep angle and because of its resistance to weathering is often a topographic feature of the region. This is a relatively thin formation which varies much in thickness from one to several hundred feet. Where this quartzite has been studied in anticlines and synclines, both normal and overturned, it appears to be younger than the banded gneiss and older than the neighboring marble.

The Marble.—The marble is a coarse-grained to medium-grained impure dolomite in which the impurities have been entirely recrystallized into silicates such as diopside, tremolite, phlogopite, etc. It is almost always a dolomite in chemical composition but may vary occasionally to a pure calcite rock. The bedding in these rocks is not easily recognized, but it is probable that the lines of impurity now represented by silicates indicate original differences in the sedimentary deposits. The amount of such impurities causes the rock to vary widely from a pure carbonate to one so rich in silicates that it may easily be mistaken for a gneiss until tested for hardness or with acid. These beds in the marble show considerable variation in the steepness of their dip, ranging from 10° up to 70° and occasionally they are found in overturned anticlines and synclines. The thickness of the formation is very variable and practically indeterminate on account of the paucity of exposures. Its presence is usually indicated by valleys along the sides of the quartzite ridges and its thickness apparently varies from nothing up to more than 2000 feet. No fossils have been found in the highly crystalline marbles and it is improbable that if originally present they could have withstood the changes which this rock has undergone.* The formation, however, has been traced

* A few deformed chert nodules have been found and they may yield microscopic forms on closer examination.

at several points into less metamorphosed rocks of similar composition where rocks of Upper Cambrian and Lower Silurian age have been found. Thus, it has been correlated with the Stockbridge limestone of western New England, the Chester Valley limestone of Pennsylvania, and tentatively with the Shenandoah limestones of Maryland and Virginia though no stratigraphic continuity has been established with the latter.

The Mica-Schists.—The mica-schist is composed of a series of highly micaceous, very schistose, and often crinkled aggregates of quartz, more or less decomposed biotite and garnet, with accessory orthoclase, cyanite, staurolite, fibrolite, etc. With the increase in feldspar the rock becomes a gneiss but is not as distinctly banded as the banded gneiss already referred to. The formation is chiefly characterized by the high content of mica, garnets, and occasional metamorphic minerals, and the small amounts of feldspar. The soils developed from the decomposition of the mica-schists are usually marked by an abundance of mica and rounded garnets. Beds of this type are only indistinctly marked and are separated with difficulty from the cleavage lines which may nearly parallel them. The entire formation has been much folded and it is not possible to make accurate determinations of the thickness. At first sight it would appear to be miles in thickness but in reality is probably not far from 2000 feet. The age of the rocks included under this term is not determinable by fossils carried by them, but, as in the case of the marbles, these schists have been correlated with less metamorphosed representatives which carry a fauna of Hudson River age.

The variation in the character of the marble through increased impurities causes the contact between the overlying mica-schist and the limestone to be one of gradation at times, and occasionally there seems to be a layer of more argillaceous mica-schists lying between the underlying quartzite and the well-defined marble.

Igneous Rocks.—Throughout the Piedmont area under discussion have been recognized numerous igneous rocks, now more or less metamorphosed, which are apparently intruded into all of the rocks as old as the mica-schists. Among the types found are granites and granite-gneisses, diorites and meta-diorites, gabbros and meta-gabbros, peridotites, pyroxenites and serpentines, meta-rhyolites, and meta-basalts. The contacts between these various masses are seldom exposed and the relative age of the various intrusions cannot be determined with entire satisfaction. So far as is known, the facts accord with the commonly accepted view that they represent in a large way a single period of igneous activity which no doubt extended over a considerable period of time. Just when these sheets

and larger intrusive bodies were thrust into their present position is not known, but the views most generally held at the present time indicate that the intrusion took place in post-Silurian time prior to the earth movements which produced the Appalachian Mountains. Earlier investigators and some at the present time express the opinion that this igneous activity was contemporaneous with the formation of the earliest rocks.

Metamorphism.—The older rocks of the Piedmont, as recognized by all investigators, have suffered more or less recrystallization and textural modification since their formation. This metamorphism has not been uniformly distributed over the entire region but, as emphasized by Williams, is much accentuated in the eastern portion of the Maryland area, where the rocks are thoroughly recrystallized and often lack in great measure their original texture. The original muds and sands of the sedimentaries have been changed to micaceous schists, gneisses, and quartzites and the various igneous rocks have been greatly modified in texture and occasionally in mineralogical composition. The textural change which is most evident is a marked development of schistosity which is to be noticed in all of the rock types already described. The change from massive to schistose rocks has not been uniform over the entire district or even over the more metamorphosed eastern section, but seems to be locally accentuated along lines which probably indicate zones of greater dynamic action.

The schistosity developed in the rocks of the Piedmont partakes of the general northeast-southwest trend of the province and varies in dip sometimes to the eastward and sometimes to the westward. It is present in both the sedimentary and igneous rocks. In the latter, it is sometimes so strongly developed that the resulting rocks in small areas present the appearance of metamorphosed sediments, although one may find all gradations between the unaltered massive types and the equivalent fissile schists. In the sedimentary rocks the schistosity is developed to a degree which greatly obscures the original bedding and oftentimes renders the determination of bedding planes impossible.

The development of schistosity is accompanied by a recrystallization of the affected rocks, which may simply result in a new development of the mineral species found in the original rock or in a molecular rearrangement producing many new minerals. Thus the gneisses are composed of recrystallized quartz, feldspar, and mica material, while the feldspars of some of the granites, the meta-rhyolites, gabbros, and diorites have been changed to epidote and the pyroxenes to fibrous or compact hornblende. The new minerals usually lie with their longer axes parallel to the planes of schistosity. In the case

of the phyllites and mica-schists the original material has been changed to muscovite, chlorite, and quartz with accessory minerals such as garnet, staurolite, cyanite, etc.

Structure of the Maryland Piedmont.

The four types of metamorphosed rocks with their accompanying igneous types unite in the Piedmont area of Maryland to form a complex geological mass in which the structure of the region is very greatly obscured by the metamorphism, secondary schistosity, and recrystallization. The problem is still further complicated by the presence of several series of minor folds which obscure the larger structural features of the region. The centering of attention on these minor structural features rather than on the broader elements of structure have led previous students of the area to divergent interpretation, or despair at ever reaching a true solution.

Previous Interpretations.—The Piedmont Plateau of Maryland has been studied by many investigators and the interpretations which they have given to the area may be classified, as suggested by Williams, into three categories, involving differences in age in the sedimentaries of the eastern and western portions of the area or differences in the structural elements which have brought the rocks to their present position. The three hypotheses as outlined by Professor Williams* are:

"1. That the rocks of both the eastern and western areas are of the same age, and that they have been bent into a broad syncline whose flanks are so sharply folded, faulted and thrust as to simulate the fan-structure observed in high mountain chains; and that the eastern flank of this synclinal or fan was much more highly metamorphosed than the western both by more intense dynamic action and by intrusion of a great amount of eruptive material.

2. That the more highly crystalline eastern area is greatly older than the western schists, and served as a rigid buttress against which these were thrust and folded.

3. That the eastern area is composed of rocks far more ancient than the western, which extend out under these, forming the floor upon which they were deposited; and that although already much folded and metamorphosed, this crystalline floor underwent at least one more folding after the schists had been laid down, carrying these with it and involving them in a considerable but not an extreme amount of disturbance and metamorphism."

The first of these hypotheses was that held by Tyson, who was State Agricultural Chemist from 1853 to 1862, and who published the first complete geological map of Maryland in

* Bull. Geol. Soc. Amer., vol. ii, p. 315.

1859. According to this view the structure is a more or less deformed synclinorium. This hypothesis, together with the second, is regarded as untenable by Williams on the grounds enumerated in his paper on the subject, where he proposed the third hypothesis as the most reasonable explanation of the facts and the one to be accepted as most probable unless subsequent explorations should render its modification necessary.

At the time Williams proposed this hypothesis no part of the Maryland Piedmont had been mapped by the U. S. Geological Survey, and the maps at his disposal consisted of inaccurate road maps of the various counties. At this time also the detailed mapping of the Piedmont, which was later prosecuted by him with success, had not been pursued beyond the immediate vicinity of Baltimore, where the structure is somewhat exceptional. The conclusions drawn were based upon several driving trips across the Piedmont Plateau in different directions, and the generalizations reached, while brilliant for the amount of information in his possession, are such as to demand modifications as the detailed mapping of the Piedmont on the scale of a mile to the inch by the Maryland Geological Survey progresses.

Results of Later Work.—Shortly after the publication by Williams of the paper referred to, the writer commenced a mapping of local areas under the former's direction and has continued field investigations as opportunity presented during the twelve years, until fully 1200 square miles of the Piedmont have been mapped on the scale of 1 : 62,500 and the entire Piedmont has been visited in economic work demanding greater or less local detail. The work of deciphering the structure of the Piedmont of Maryland is by no means ended, but it is proposed to give in the following pages what are believed to be the general lines of structural uplift and depression across the area. Many local questions still remain unsolved and much detailed mapping is still necessary in the western portion of the Plateau, but the views here expressed have been found to present the most reasonable interpretation of the area studied. Moreover, while they have been developed independently they are found on comparison to be more or less in accord with the structural interpretations resulting from the most recent work in corresponding areas to the north and south.

The methods employed in the investigation of the Piedmont geology embrace a consideration of all of the data available under the conditions encountered. The region considered lies south of the zone covered by the continental ice, and as a consequence few exposures of fresh rock are encountered except in the recent stream cuttings or in artificial openings. At the same time, bowlders and disintegration products found on the

surface are usually indicative of the character of the underlying rock. Throughout most of the area, especially in the little-dissected remnants of the old peneplane, the disintegration has extended from one to twenty or thirty feet, according to the character of the rock, and one may find entirely disintegrated masses of clay or sand retaining the original textures of the parent rock. Even much of the material which at first is so hard as to require blasting, breaks down when exposed for some time to the influence of the atmosphere. Disintegration of this type leaves few exposures and renders microscopic studies of many apparently fresh specimens unsatisfactory, but in turn facilitates the areal mapping since the soils and minor features of the disintegrated products are often characteristic of the underlying rock. The plant cover is also occasionally distinctive since certain forms of plant life are found limited to the areas underlain by certain rock types or there possess certain peculiarities of development.

The lack of fresh exposures and the detailed complexity produced by the schistosity and minor plications make it exceedingly difficult to determine the true bedding plane, and this is not possible in many instances. It becomes necessary therefore, to lay relatively less stress on the structural features found in single small exposures and to assign greater importance to the areal distribution and the general structural features determined by it.

Fossils have been found in only one or two areas, where they are much distorted or damaged and there is little hope that other deposits of better preserved forms will be found; for only the most hardy forms could withstand the metamorphic changes which the rocks have undergone.

The types of structure encountered in the region are joints, normal faults (usually of small throw), folds and probable unconformities. The *jointing* is usually in three fairly well-defined series of joints which cause the rock to break into irregular rhomboids. When well exposed in the banded-gneisses of the Baltimore and other areas, they show little or no movements along their planes although now and then a displacement of a few inches may be found along fault planes which are more or less parallel to the planes of jointing. The *faulting*, if present, is usually obscured by the homogeneous character of the rocks and the lack of well-defined bedding in many of the sedimentary masses where the faulting is exposed. It is accordingly impossible to trace the faults beyond the exposures in which they are found. So far as examined the throw of these faults is slight, ranging from a few inches up to a foot or two, and the general faulting structure partakes of that characteristic for the Jura-triassic beds which overlie the Piedmont on

its western border. Large overthrust faults may perhaps occur in the region, obscured by the similarity of deposits and the vegetation, but no evidence up to the present time has been found warranting the assumption of such overthrust faults unless, perhaps, in the region a few miles west of the Northern Central Railway, at a point twenty-five miles north of Baltimore. If such a fault occurs here, the plane of the overthrust must be very flat and the extent of the thrust small, since the areal distribution of the phyllites to the north and the gneisses to the south show no appreciable break in their boundaries. It seems more probable to the author that the recurrence of the marble in a series of parallel bands is due to folding or minor faulting than to an overthrust.

The *folding* in the rocks of the area is of three types: minute crinkling, small unsymmetrical wavy folds, and broad Appa-

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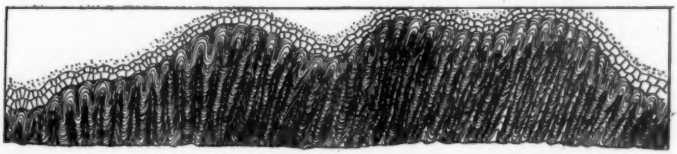

lachian ones in which the adjustment appears to have taken place along the bedding. The accompanying figure indicates the differences as sketched from exposures in the field. The intricacy of the minor folds has been the feature usually noticed by earlier investigators, who have many times overlooked the gentler open folding of the larger folds. In the succeeding discussion the emphasis will be laid upon these larger folds and less attention will be drawn to the minor ones, since the broader rather than the detailed local structure of the Maryland Piedmont is the problem under discussion.

The dip observations made on small exposures often relate to the minor folding and are usually quite steep, ranging from 40° to 80° with an average of 55° in the exposures. These dips are usually considerably at variance within short distances, although there seems to be a tendency for the exposures to be formed on those portions of the minor folds where their dip is in the same direction as that of the major fold, the return dips being usually concealed. The earlier structural interpretations have been based for the most part, in Maryland at least, on the dips of these secondary folds, and it has accordingly been customary to regard the region as one of steep monoclinal or closely compressed overturned folding. The dips of

the major folds, as determined by tracing individual beds with their sinuosities across the larger exposures, are much flatter than those of the minor folds, usually ranging in value from 5° to 40° with an average of between 25° and 30°. In many instances it is not possible to determine this major dip, but the areal distribution of the rocks is generally found to be in harmony with such observations as can be made.

Overturned folds are occasionally encountered, the best example so far studied occurring just west of the Baltimore-Harford county boundary line, about five to ten miles south of the phyllite boundary. The structure here is well marked by the occurrence of a quartzite, an intermittent marble, and the mica-gneisses surrounding a core of banded mica- and hornblende-gneisses. Contrary to the usual interpretation, this large fold is overturned to the southeast, causing all the dips to slope to the west.

Unconformities apparently occur in the crystalline rocks of the Piedmont, especially at the base of the quartzite and the top of the marble, but it is very difficult to determine whether or not the latter is due to a change in the character of the original limestone which, when highly argillaceous, is metamorphosed into a calcareous gneiss or mica-schist which is practically indistinguishable by field observation from the adjoining rocks. The points where this unconformity has been supposed lie near the limits of the area in which marble occurs, and it seems highly probable that the conditions of the formation of a limestone became less favorable around the limits of the area, and that through gradation the limestones pass off into rocks which, when metamorphosed, are indistinguishable from the overlying mica-schists.

Geological Sequence.—The field work conducted by the author and his associates on the Maryland Geological Survey indicates that in the Maryland Piedmont we have the following series of metamorphosed rocks which were apparently of sedimentary origin.

Peach Bottom slates Cardiff quartzite	Silurian (?)
Wissahickon phyllite, mica-schist and mica-gneiss	Ordovician
Cockeysville marble	Cambro-Ordovician
Chickies quartzite or Setters quartz schist	Lower Cambrian
Baltimore gneiss	Pre-Cambrian

The determination of the age of these formations by fossils is impossible at the present time in Maryland, and the age assigned the various beds is therefore regarded as somewhat

unproven, but, as already outlined in the first part of this paper, the sequence here is comparable to that of the similarly situated areas farther north where they have been correlated with less metamorphosed beds bearing fossils. The lithological features and structural characteristics are the same in the different regions and it is probable that this correlation is the true one and that it must, perhaps forever, remain unproven for certain portions of the Maryland region where the beds are separated from other sedimentaries by igneous rocks. As the work now in progress under the joint auspices of the Maryland and U. S. Geological Survey goes forward, it may be possible to correlate on structural grounds the limestones with fossil-bearing beds near Frederick, and it is possible that well-preserved fossils may be found in the less metamorphosed sedimentaries of the Frederick valley to the west of Parr's Ridge, as Mr. Keith has already detected fragments in this region.

Igneous Rocks.—Through these sedimentary rocks have been intruded large masses of igneous material which have consolidated into granites, gabbros, and other igneous types. Formerly it was regarded that the masses were intruded in pre-Cambrian time and that they were contemporaneous with the metamorphism of the crystallines. This cannot be wholly the case if the foregoing interpretation of the age of the sediments is correct, since these igneous rocks are intruded into the rocks here considered of Silurian age.

The areal distribution of the formations enumerated above is given in the accompanying map (Plate X) which has been compiled from the published maps of the New York and Pennsylvania state surveys; from the New York and Washington folios of the U. S. Geological Survey; and the manuscript maps of Dr. Bascom and the writer. The scale of the map has required more or less distortion in the representation of the quartzite and limestones and in the mapping of the rocks of the less metamorphosed western portion of the plateau. The lines must therefore be regarded as only provisional, especially in the areas north of Washington and that part of Pennsylvania which has not been mapped by Dr. Bascom.

General Structural Lines.

The broad structure lines of the Maryland Piedmont, so far as they have been worked out in the eastern or more crystalline portion, are indicated in the accompanying sketch by lines occupying the axes of the synclines and anticlines. It is impossible on any small scale map to represent the minor structural lines, which of course more or less modify the position of the axes of the major folds. It is believed, however,

that the lines here indicated represent the structural characteristics up to the scale of the base employed. The individual axes distinguished in the area are described in greater detail in the following discussion.

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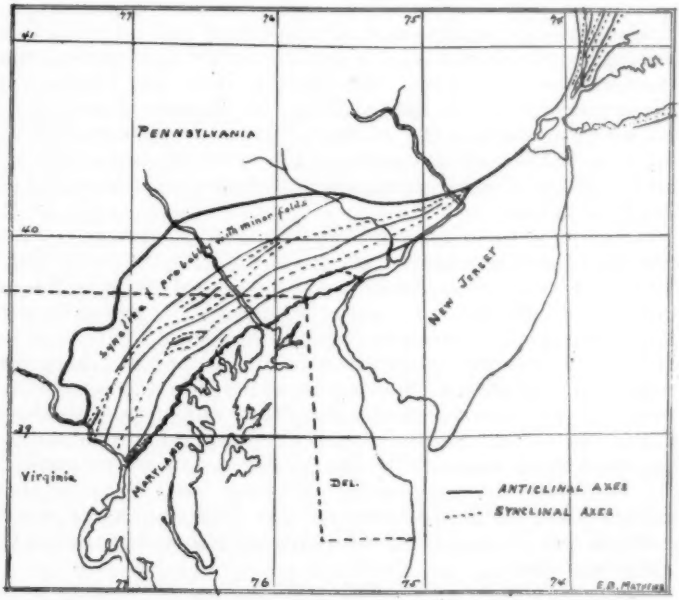


*Structure Lines of the Piedmont.**

East Alexandria–Winters Run Syncline.—Poorly exposed syncline extending from Churchville to east of Baltimore, east of Washington to Alexandria. Covered for the most part with Coastal Plain deposits and largely hypothetical. As shown in Harford county, this axis is plunging southwest.

Washington Uplift–Towson–Belair Anticline—A rather shallow anticlinal axis which may in reality be composed of several minor ones, recognized by Keith as a portion of his West Washington anticlinorium. Occupied for the most part by gabbro sheets on either flank. Probably the line passing from the vicinity of Belair eastward through the central Piedmont district of Cecil county and possibly corresponding to the eastern anticlinal axis suggested by the older gneiss of the Philadelphia

* When the terms "anticlinal axis" and "synclinal axis" are used it is not intended to convey the idea that the lines are of simple structural folds but that these lines represent the dominant axes of anticlinoria and synclinoria. For local points see maps of National and State Geological Surveys.

area. Apparently plunging to the northeast, but this is not clear. These two axes lie within the limits of what are regarded as possibly Archean gneiss areas.

Caves–Forest Hill Syncline.—A well-defined synclinorium extending southward from Scarboro to the area between Green Spring and Worthington valleys in the Baltimore quadrangle. Plunging to the sonthwest. At the Caves the center of this synclinorium is occupied by a small anticline which brings the limestone to the surface. Southward from the Caves the axis apparently extends to the Clarksville–Highlandtown region and probably corresponds to the sag between the two lines of uplift in Keith's anticlinorium. The synclinal basin east of Buck's Ridge, Pennsylvania, may represent a continuation of this general line.

Cabin John–Jarrettsville–Bucks Ridge Anticline.—An overturned anticline beginning west of Jarrettsville on the Taylor Valley road and extending southwestward through Manor and Western Run on the Parkton quadrangle; is probably part of the general anticlinal axis which is represented to the southwest by the imperfectly studied axial line determined in great measure by the strong synclines on either side. It is approximately in the same position as the strong uplift recognized by Keith near Cabin John on the West Washington quadrangle. Eastward from Jarrettsville the anticlinal axis is less marked and is apparently occupied by the long band of serpentine which crosses the Susquehanna river at Bald Friar and extends eastward into Pennsylvania, where it is represented by the Bucks Ridge anticline.

Glencoe Syncline.—A small synclinal axis extending from Glencoe on the Northern Central Railroad southwest through Priceville to Mantua on the Parkton quadrangle and apparently separating the lines of the anticlinal axes on either side, bringing to the surface along Western Run some of the overlying limestone. The structure in this region has not been thoroughly worked out and there may be a small thrust fault.

Cardiff Syncline.—A strongly-marked synclinal basin with its greatest depth in the neighborhood of Cardiff, Maryland. This conforms to the center of the phyllite belt as far as that has been traced. It apparently connects with the synclinal axis recognized by Keith as passing just east of Great Falls. This syncline carries the youngest rocks of this portion of the Piedmont Plateau and has been recognized as a structural feature for many years by the Pennsylvania and Maryland geologists. The bedding in this basin is no more distinct than in the basins and folds previously described, but the presence of the small quartz conglomerate at the base of the slates as well as the slates themselves have made the recognition of its presence

much easier. It seems to be a southern extension of the Chester Valley folding,

Tocquan Anticline.—Tocquan anticline, recognized by Professor Frazer in his report on Lancaster county (CCC, p. 128) as a broad flat anticlinal arch somewhat tilted to the southeast, crosses the Susquehanna river at McCall's Ferry. This structural line has been traced by the Pennsylvania geologists from northern Chester county through Lancaster and York counties to the Maryland line. Throughout this area the axis is complicated by the presence of minor folds. It seems to rise to the north and south. In Maryland the work along this axis has not been carried very far, but the areal distribution of the rocks seems to indicate that it corresponds roughly with the center of the mica-schist zone passing east of Westminster, crossing the Potomac to the southwest of Rockville. The occurrence of interfolded phyllites along the western boundary of the more crystalline part of the plateau, as worked out by Keith, and of phyllites farther south to the west of Gaithersberg, suggests that this axis is here even less strongly marked and that it is broken into several shallow folds.

The region between this anticlinal axis and the overlapping Jura-trias bed on the west appears to be a shallow much-folded synclinorium with an anticlinal axis passing near Union Bridge, Maryland, but this region has not been worked with sufficient detail to warrant more definite statements.

On the eastern side of the Catoctin mountain the Shenandoah limestone rises with an easterly dip from beneath the phyllites and is in turn underlain by the Antietam quartzite and other rocks of Cambrian age.

Character and Distribution of the Igneous Rocks.

The most prominent feature of the igneous rocks is the occurrence of large masses of gabbro in more or less parallel bands, separated for the most part by masses of granite and smaller areas of ancient gneisses. The areal distribution of these gabbro masses, which in the region about West Chester, Pennsylvania, have been found by Dr. Bascom to extend across from one belt to the other, is believed by the author to indicate that the various occurrences represent what was once an immense gabbro sheet extending from Laurel, Maryland, to the Schuylkill river, a distance of fully 85 miles with an exposed breadth of at least 15 miles.

Through this great sheet of gabbro were apparently intruded the granites and later meta-rhyolites and pegmatites, the whole constituting one great series of igneous activity. When these intrusions began or when they ceased is not clearly determinable since contacts between the various rocks are almost

entirely lacking, and any contact metamorphism which they may have imposed upon the rocks existing at the time of their intrusion is now obscured by the subsequent metamorphism which they and the associated country rock have undergone. From the fact that parts of this igneous complex are intruded into the rocks regarded as Silurian in age, this activity could not have ceased prior to the later portion of the Silurian and may have been much later. That the intrusions are not younger than Paleozoic time seems to be an inference well supported by the fact that they along with the sediments partake of the broad folding characteristic of the Appalachian region to the westward, which was probably developed contemporaneously in the rocks of the eastern and western portions of the state. Moreover, the sedimentaries of Jura-trias time show little folding of this type, their deformation being due almost entirely to very gentle folds and small faults of slight throw.

Relation of the Eastern and Western Districts of the Piedmont

The division of the Piedmont Plateau into an eastern division composed of much metamorphosed, highly crystalline rocks, and a western division characterized by less metamorphosed, so-called semi-crystalline, rocks has long been recognized but was first sharply emphasized by the late Professor Williams in 1891. He regarded the eastern area as composed of rocks far more ancient than those in the western district and that they extended westward, forming a floor upon which the younger phyllites were deposited. He also believed that the eastern portion had already been much folded and metamorphosed before the phyllites had been laid down. As conclusive against the identity of age of the semi-crystalline and holocrystalline rocks he summarized the following points.*

a. The structure is not really a synclinal, but a fan-like divergence of dip from a central vertical axis, such as could not be produced by any synclinal bending in a continuous series of similar beds.

b. Any cause altering any part of an original series more than another would not make an *abrupt* contact, such as we find between the semi-crystalline and highly crystalline rocks of Maryland, but a gradual transition.

c. Any cause altering one flank of a synclinal more than the other would make the contact between the two kinds of rock and the axis of the synclinal coincide, as is not the case in Maryland.

d. The eruptive rocks of the eastern area are found in many places in close proximity to the slates or schists, without having effected their alteration; hence they are either not the cause of metamorphism, or they are themselves older than the semi-crystalline rocks; and, moreover, the sudden disappearance of the abundant eruptive rocks at the edge of the western area is itself a strong reason for supposing that it is of later age.

e. We cannot suppose that excessive dynamic action was the cause of the metamorphism, because where we should expect the folding force to have acted equally we find the hardest rocks (eruptives) much more altered, foliated, and disturbed than the soft argillites.

* Bull. Geol. Soc. Amer., vol. ii, 1891, p. 316.

The generalization reached by Williams in this paper is one of far-reaching importance and marked his ability to gain clean-cut conceptions of intricate problems from the most meager investigations. The writer has had occasion to re-examine most of the areas studied by Williams and has been impressed with the grasp of the subject and accuracy of the conclusions drawn when judged by the amount of information at his disposal. It should be borne in mind, however, that at the time this paper was written and even up to the date of Dr. Williams' death, only a small portion of the Piedmont in Maryland had been mapped by the topographers of the U. S. Geological Survey and not all of this had been studied in detail geologically. The generalizations drawn were based upon rapid reconnaissance driving-trips across the Plateau rather than upon detailed examinations carried on throughout the region.

Bearing these facts in mind, it is no serious criticism to Williams when the writer asserts that the detailed work of the last ten years, conducted with greater opportunities and with the aid of topographic maps, shows that the facts on which Williams based his conclusions are not proven. Taking up the five points regarded by him as conclusively proving that a time break exists between the eastern and western rocks, the writer would call attention to the fact that the "fan-like divergence of dip from a central vertical axis" does not seem to be a correct interpretation of the structural lines found within the region, which, on the contrary, indicate that there has been a series of folds rather than a single syncline or fan-like structure. The apparent occurrence of such a structure is due partly, no doubt, to the confusion of true bedding planes with those due to schistosity. The abrupt contact, such as Williams seemed to find between the semi-crystalline and highly crystalline rocks of the Piedmont, apparently does not exist with the sharpness formerly supposed, since Keith's work in Carroll and Howard counties has broken the sharp line drawn by Williams into an intricate series of intertonguing areas. The contact between the so-called phyllites and the gneiss as drawn by Williams is, in most cases, a contact between the phyllites and the mica-schists and gneisses of Hudson age rather than with the banded gneisses believed to represent pre-Cambrian. The contact here, judging from the experience of more recent workers in the region, is not abrupt but is usually obscured by the similarity of material or the likeness of soil resulting from the mica-schists and banded gneisses.

The fact that the igneous rocks of the eastern area when in close proximity to the slates or schists show little metamorphism, may be explained by the fact that within the Maryland

area only relatively small bodies of serpentine and granite come in contact with the younger gneisses and schists, and where such is the case the intrusive body has been so small as to produce no appreciable metamorphism. Moreover, if any contact metamorphism occurred, it would now be practically unobservable since the entire region has been more or less metamorphosed and contacts are almost entirely lacking in fresh rock. "The sudden disappearance of the abundant eruptive rocks at the edge of the western area," as inferred by Williams, is now recognized to be a conclusion not wholly in accord with the facts. Keith in his work in Frederick county found numerous bodies of aporhyolite and metamorphosed acid volcanics and this find has been corroborated and extended by the field work of the writer. In this region of so-called semi-crystalline rocks the eruptives found by Keith and others have been so metamorphosed into sericitic schists that they are scarcely distinguishable from the nearby phyllites except for the presence of small quartz and feldspar phenocrysts.

The points raised by Williams that the contact between the rocks of the eastern and western areas does not coincide with the axis of the syncline and that the eruptives were much metamorphosed at points where one would infer from the structure but little metamorphism, involve the assumption of a rather simple synclinal or fan-like structure which has already been shown to be discordant with the facts as developed by later and detailed investigations.

From the foregoing paragraphs it may be readily seen that the writer does not believe that the points raised by Williams validly disposed of the contemporaneous age of the rocks in the eastern and western portions of the Piedmont. Moreover, the detailed work of Keith on the west and the reconnaissance work by the Maryland Geological Survey on the north, point to an infolding of the various rocks which ultimately may show their similarity in age, when the detailed work has been completed.

Conclusions.

From the past ten years of work in the detailed mapping of the Piedmont rocks of northern Maryland the author has been led to the following conclusions as best in accord with the facts in hand:

1. The older rocks of the Piedmont consist of both sedimentary and igneous types which since their formation have been more or less metamorphosed.

2. The metamorphosed sediments include banded micaceous and hornblende gneisses of pre-Cambrian age; a more or less intermittent thin-bedded generally tourmaline-bearing quartz-

ite of Cambrian age; an intermittent dolomitic marble or magnesian limestone of Cambro-Ordovician age; and a series of mica-shists and the gneisses of Ordovician age. Above these occur a somewhat intermittent poorly developed quartzitic conglomerate and the Peach Bottom slates.

3. The igneous rocks consist of an immense gabbro sheet, intruded by numerous large bodies of granite and meta-rhyolite, and accompanied by numerous more basic serpentinized bodies. These various masses represent stages in a single extended period of igneous activity.

4. The time when this activity took place was later than early Silurian and earlier than the late Carboniferous; probably in the early part of this interval.

5. The chief structural features of the region are the metamorphism and constant schistosity and the broader folding of the different rocks.

6. The metamorphism of the rocks, especially of the banded gneisses, probably commenced prior to the intrusion of the gabbro and granite and was accentuated by them in the eastern portion of the Plateau.

7. The folding of the region is of the Appalachian type, the rocks occurring in several long, more or less parallel folds, with few faults and but occasional overturned folds.

8. The eastern and western areas are probably of the same age; differences in metamorphism being due to the large bodies of deep-seated intrusives on the east and the smaller bodies of surface volcanics on the west.

9. The sequence found in Maryland may be recognized from Washington to Trenton and in the region north of New York.

If these conclusions are confirmed by later investigation, it will be necessary to modify the generally accepted hypothesis of a former mountain range along the eastern Atlantic now represented by the Piedmont Plateau; or the location of this hypothetical range, which is supposed to have supplied the sediments for the Appalachian sea during Paleozoic time, must be shifted, at least for the earlier Paleozoic, farther east where its roots would not lie buried under Coastal Plain deposits.

Johns Hopkins University, November, 1903.

Art. XII.—*Direct Micrometric Measurement of Fog Particles;* by C. Barus.

1. *Introductory.*—Before using the data computed for the dimensions of fog particles in the reductions of my observations of atmospheric nucleation,* it seemed expedient to endeavor to obtain corroborative values by some straightforward method. Aitken's dust counter had naturally suggested itself early in the course of my work; but the results so obtained are essentially indirect as the fog particles are not themselves observed. It was necessary, therefore, to devise apparatus by which the identical fog particles of a given corona could be directly entrapped and held for examination. This was eventually accomplished in a way admitting both of the measurement of the diameters of the particles and, probably, of counting the number precipitated under known conditions. Moreover, the particles caught, however fine (even less than ·0003^{cm} in diameter), can be kept in place for observation, so that microscopic photography is applicable not only for the purpose of obtaining size but (possibly) number.

Many investigations are thus suggested, as, for instance, a repetition of Thomson's method for determining the charge of an ion; an experimental test of the subsidence equation for small spherules, etc. Again, while the corona gives merely the average size of the cloud particles, the microscope is particularly available for indicating variations of diameter for the particles of the same corona. In fact, the water particles when caught are not of a size; they are graded and hence the nuclei are probably also graded in size.

2. *Apparatus.*—Aitken's beautiful and highly ingenious instrument† is well adapted for the work for which it was designed; but it will not subserve the present purposes. Aitken's droplets evaporate too rapidly in spite of their artificially increased size. The need of mixing atmospheric air and dust-free air with shaking and stirring is an interference with the nucleation. In fact, water nuclei may even be generated in this way, possibly by the friction of air passing across damp surfaces. There is the tendency of the plate after long use to fog permanently or to collect droplets on its own account. Finally, it would be very difficult to remove the contents of the coronal chamber to the dust counter without changing the nucleation during the transfer.

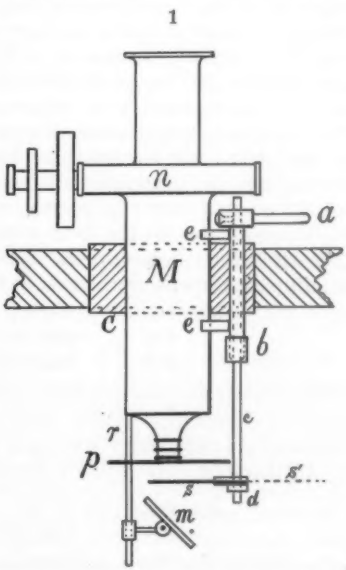
I therefore endeavored to ascertain whether the particles

* Phys. Review, xvii, p. 233, 1903; cf. ibid., xvi, 193, 246, 1903.

† My thanks are due to Mr. A. L. Rotch, who was good enough to lend me his dust counter.

might not be made visible directly. The chances of success seemed small indeed, in particular as Assmann* had failed to see the particles with the magnifications of even 400 diameters. But after long trial, the result was eventually accomplished in a way that now seems surprisingly simple.

The compound microscope, *M*, magnifying about 100 diameters, is provided with a filar ocular micrometer, *n*. The objective and the whole lower part of the microscope is submerged in the condensation chamber, being suspended for this purpose from the wide rubber cork, *C*. All lenses below *C* are hermetically sealed with wax. The microscope originally carried a rigid stem, *r*, to which were then attached the plate, *s*, to be examined, the mirror *m*, and the metallic disc or shield, *d*. Afterwards the more flexible adjustment shown in the figure and described below was adopted. The lower side of *p*, which is flush with the objective, and the upper side of *s* are covered with wet blotting paper, the latter being perforated to admit light into the microscope through the thin cover glass placed at *s* and held sharply in focus by a suitable clip. The field within which drops are to be counted is bounded at pleasure by the wires of the micrometer.



This apparatus was totally unsuccessful. Drops were but rarely seen to fall on exhaustion, while the dew soon gathered on the plate *s*, in such a way as to be easily mistaken for droplets; for the dew evaporates like the latter when the microscope is removed, and the regularity of the pattern on the plate is the only distinguishing feature.

Various modifications of this apparatus were then used, among them capsule forms similar to Aitken's, but containing a very thin plate of glass or mica or celluloid slightly raised above the base on pellets of wax. It was supposed that this would counteract the tendency of the drops to vanish by evaporation from the warmer glass surface. Capillary metallic

* Cf. Arrhenius, Kosmische Physik, vol. ii, p. 487, 1903.

tubes led to the "curl" aneroid, the filter, and to the cock for influx of air, the only large tube being the exhaust pipe. Condensation again occurred as a microscopically granular deposit spontaneously on the raised surface, under all circumstances, and the experiments were failures. After oiling the raised filmy mica surface, however, droplets were often seen to fall and either to stick fast or to float. These could at times be counted (2000–5000 per cub. cm.); but the rapid evanescence of precipitated droplets and the failure of all attempts to reach systematic results induced me to abandon the capsule.

I therefore returned to the apparatus in figure 1, using at s a plate of thin microscopic glass covered with a film of oil and exposed in the capacious vacuum chamber. The experiments were now phenomenally successful. Thus for the aperture $s = 5$ the mean results were $n = 150{,}000$, and for $s = 4{\cdot}6$ (w g b p), $n = 140{,}000$. The precipitation of globules was clearly seen and they persisted even after the exhaustion was removed. The numbers being excessive and referable to globules swept in by lateral air currents, an improvement was now added by increasing the diameter of the disc p to about 5^{cm}. The improved apparatus gave no results whatever, and the mere addition of the wider disc wiped out all precipitation. But this capricious behavior is characteristic, for next day with a smaller disc drops were seen to fall as follows:

$s = 4{\cdot}5$	w g b p	$n = 6{\cdot}5 \times 10^4$
$4{\cdot}6$	w g b p	$4{\cdot}7$
$6{\cdot}3$	w g b p	$13{\cdot}3$

after which no precipitation could be caught in the six subsequent exhaustions by the identical method. The same unaccountable irregularity was noted in the afternoon. Next day again the first experiments showed

$s = 6{\cdot}0$	w c g	$n = 7{\cdot}3 \times 10^4$
$6{\cdot}4$	w g v p	$12{\cdot}4$

after which further precipitation did not occur.

The apparatus was then again modified to the final form shown in figure 1, by inserting a thin brass tube laterally through the stopper C, and firmly soldering this tube at e above and below to the body of the microscope. A rod snugly fitting the tube thus provided an eccentric focussing device, *abcd*, with a stuffing box at b, and an external handle at a. The latter is adjustable by aid of a set screw so that the plate s may be kept in focus during rotation of the rod. To catch the droplets, the plate s is rotated into the position s' quite beyond the shield, p, for a time (15–30 seconds) and then returned to s for examination. In this way the definite

results were obtained, in a manner to be further detailed below, with the apparatus free from capricious behavior. It is of particular interest that the particles caught on the oiled surface persist as brilliant round globules for a long time (10 min. or more) in a saturated atmosphere. They very gradually vanish as a rule, on the readmission of air into the condensation chamber.

To remove the globules for the next experiment the influx of air is thus not generally sufficient. It is necessary to withdraw the microscope from the condensation chamber bodily and to wave it about a few times in dry air. On returning it to the chamber the plate is then again clean and white.

At first the plate was oiled by a small flat piece of blotting paper saturated with oil and held on a stem, care being taken to remove all excess. Clean machine oil or ordinary illuminating oil, or a mixture of the two, subserved the purpose about equally well. Probably the best method of oiling consists in dipping the plate rotated outward to s' in very hot melted vaseline (to drive away moisture), removing the excess while hot by filter paper, and when cold submerging the plate in petroleum for transparency. With solution of vaseline in benzine, etc., I have been less successful.* A film of varnish dried and soaked in turpentine was used. When drops are to be counted by the method given below, the oil film must be practically solid; otherwise the capillary forces produce an immediate and often startling redistribution of the precipitated granules, though they may not coalesce.

3. *Behavior of the precipitated droplets.*—In case of a petroleum film on the plate, the water droplets were sometimes seen to fall and float on the film, which is positive evidence against spurious droplets. They are usually black and circular in outline, but when the light is intense and axial, they are often colored. Fixed globules were apt to be larger and more irregular and pink or red in color. The color was eventually traced to the chromatic aberration of the objective used. This defect was rather useful in detecting clear globules, but it would be fatal in photography.

On tipping the microscope so that the light does not penetrate the vividly colored drops axially, they seem to cast shadows in opposed directions for symmetrical inclinations on both sides, as in fig. 2; but the phenomenon is probably a case of refraction† with the shadow beginning at the edge of a dis-

* It has thus far been difficult to produce an oily film free from flaw and quite glossy under the microscope, where surfaces are apt to be either reticulated or fluid.

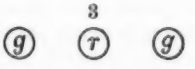
† That the effects described are associated with the aplanatic foci of spheres (as I at first supposed) is improbable. The globules lie on the oil film through which nearly parallel light enters. The caustic is not shown in fig. 2.

tinctly visible caustic. Similarly on moving the lamp horizontally to either side from the position corresponding to vivid pink color, fig. 3, and axial illumination, the globules become opaque and look like round shining steel beads. The diameter of the beads has but little effect on the axial or the other color.* If the lamp is moved until the field is dark, the plate looks like the starry heavens. These "stars" or foci are seen to be above the drops. They should lie (roughly) ·0003/·33 to ·0015/·33^{cm} above it.

2

After remaining in the plate for some minutes the fixed droplets often become rosette-shaped (apparently), at first (fig. 4) showing a mere black spot in the center of the color disc which gradually enlarges to a ring-shaped appearance *slowly moving radially outwards.* As a rule, the color is eventually the same on the inside and the outside of the enlarged ring, the ring itself appearing red with black demarcations in the surrounding green field as shown in the figure. On influx of air the structure becomes washed. The small globules when at first deposited never show the same color within and without, the former being uniformly red and the latter white. As the rings are not easily produced with a very viscous oil, it is

3



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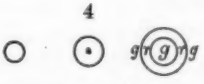


probable that the droplet has here penetrated to the glass and that the oil film is drawn over it by the capillary forces at the common edge of the three media. But the cause of the radial expansion is an interesting subject for conjecture.

4. *Preliminary measurements.*—Before adopting the eccentric focussing device, many experiments were made to ascertain the cause of the uncertainty in catching the drops on the plate when kept in place, seeing that sometimes the precipitation was abundant, while at other times, under the same apparent conditions, drops did not fall. Failures occurred both for high and for low nucleation. From the outset it was improbable that radiation from the outside could affect the result. It was eventually ascertained that on tipping the con-

* The degree of transparency will depend on the amount of contact of the globule and the oil film, and the floating globules are therefore sometimes quite opaque, at other times partially or wholly transparent.

densation chamber, after the fog had formed so that the subsidence would reach the plate obliquely, a precipitate would usually appear. Again, an oblique current within the chamber and passing across the plate usually produced a deposit. Hence, as the drops actually exist within the fog, success in bringing them down upon the plate is conditioned by very close isothermal adjustment of the plate to its surroundings, added to the advantages gained from incidental and favorable air currents. Thus a little time must always elapse before the drops persist at the plate, and therefore the droplets from a shallow capsule do not appear. Using a film of mica as a plate the result was the same, and it is useless to attempt to enumerate the drops by this method. Those which fall are carried in by grazing air currents, while no drops are obtained from the fiducial space under the objective. Cf. § 5.

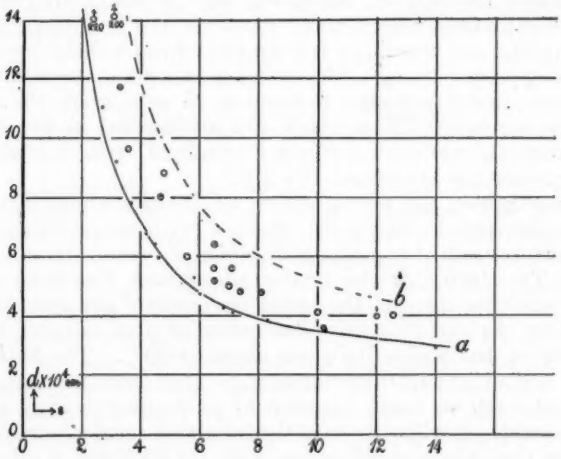
Nevertheless, the measurement of the diameters, d, of the drops obtained by the given method without modification is an excellent test of the results obtained elsewhere by computation. The factor of the ocular micrometer described above was $\cdot 002^{cm}$ per turn of the screw or $\cdot 00004^{cm}$ per scale part of the drum divided into 50. The extent of plate covered by the breadth of the spider lines was about $\cdot 0003^{cm}$. The finest particles are of about this diameter, so that such measurements must at best be much inferior to photography with a scale attachment. I will pass over the tabulated results here, merely stating that the coronal color with its diameter, s (chord of a radius of 30^{cm}), was observed when the eye and the source of light (Welsbach mantel seen through a small circular hole) were at distances 85^{cm} and 250^{cm}, respectively, from the center of the condensation chamber. The exhaustion was usually to a pressure difference of 17^{cm}, but this is of no significance when diameters are alone to be measured. The particles were collected by tipping the chamber, sometimes in large numbers, but at other times sparsely distributed without apparent cause. Nuclei were conveniently obtained from burning charcoal. Both floating and fixed globules were examined with strong microscopic illumination. It was difficult to retain a clear image without frequently removing the plate as the adjustment for focussing the plate within the chamber had not yet been adopted.

Floating globules were sometimes observed in the act of coalescing; but this is much rarer than the passage of a floating droplet* over a fixed one without interference. A distinct central red area, shading off into darkness, was seen even in the floating globules when axially illuminated by intense light. The larger drops were often metallically green. The colors

* Multitudes of fog particles are often seen moving in opposite directions across the field and turning about normally at the edges of a liquid film.

(chromatic aberration) vanish after long standing and they are particularly vivid immediately after falling. It was not even now possible, in spite of all precautions in tipping the vessel, to obtain an abundant crop of drops at pleasure.

If the results are given graphically in a chart in comparison with the computed data of my earlier experiments* as well as with my later† experiments, the observed results lie below the



latter where adiabatic conditions were assumed, and above the more recent experiments where the effect of the successive expansions was computed isothermally. In other words, the observed diameters were intermediate but nearer the older results.

5. *Number of droplets.*—The following results were obtained with the definite form of apparatus shown in figure 1. A method of estimating the nucleation from a direct count made under the microscope is obtained as follows: Let the plate s be rotated to s' so as to catch the descending fog particles for a definite interval of time, t. If v be their velocity of subsidence, all particles within a height, h, will be caught, if

$$h = vt \qquad (1)$$

and

$$v = 10^6 d^2/3{\cdot}24 \qquad (2)$$

where the usual value of the viscosity of air has been inserted. Furthermore, m grams are precipitated per cub. cm. by the given exhaustion, and if n be the nucleation

$$n = 6\,m/\pi d^3 \qquad (3)$$

* Phil. Mag. (6), iv, p. 24, 1902. See curve *b* in the following chart.
† This Journal (4), xvi, p. 325, 1903. See curve *a* in the following chart.

Finally if c is the area of the field seen in the microscope and n' the number of particles falling into this field

$$n' = n\,h\,c \qquad (4)$$

From these equations n is obtained by eliminating v as

$$\sqrt[3]{n} = \frac{2{\cdot}11 \times n'}{t\,c\,m^{2/3}\,10^6}$$

The values of the constants usually adopted were $t = 30$ sec., $c = 144 \times 10^{-6}$ sq. cm., $m^{2/3} = 2{\cdot}8 \times 10^{-4}$, whence $\sqrt[3]{n} = 1{\cdot}75 \times n'$.

The experiments to test this method often gave serviceable results some of which are inserted in the following tables; but at times the n-values are out of proportion. The reason of this is three-fold: In the first place n is found from $n^{1/3}$ with the usual difficulty. Again, in a simple arrangement like the above, air currents cannot be quite excluded. They may arise incidentally in the apparatus, or the motion of the plate even,

TABLE I.—Observed diameters (d) of cloud particles and numbers (n) per cub. cm. $m = 4{\cdot}7 \times 10^{-6}$ g per cub. cm.; micrometer factor ·00004cm. Distances of goniometer and light from condensation chamber, 85cm and 250cm; chord s for radius 30cm. Exhaustion to $\delta p = 17$cm.

	s	corona.	$c \times 10^6$	t	n'	n observed.	n computed.	d observed.	d computed.
	cm.		cm.²	sec.				cm.	cm.
	----	olive	140	30	37	270000	250000	----	----
	6·0	w r g	140	30	27	105000	90000	----	----
Phosphorus nuclei	10·2	w o b g′	70	30	17	210000	210000	·00036	·00036
	7·4	w p b g	70	15	6	----	----	48	41
	7·1	w′ b p	----	--	----	----		56	42
	4·7	corona	----	--	----	----		80	61
	Particles as small as ·0003cm present throughout.								
Do.	6·5	g b p	140	15	10	43000	100000	·00064	·00046
	6·5	g′ b p	----					56	46
	Particles graded as usual.								
Air Nuclei	4·5	corona	140	15	9	30000	40000	·00064	·00064
	6·5	g′ b p	----	--	----	----		52	46
	8·1	w c b g′	70	15	14	120000	150000	48	39
	8·2	Do.	70	15	16	180000	150000	----	39
	Particles graded as usual.								

if parallel to itself, may stir the air unless some form of guard ring attachment is added. Particles are thus swept down

upon the disc before and after the exposure, as was actually observed. The difficulty may be removed by adding a capsule above the plate or simply by decreasing the distance between the shield and the plate to a millimeter or less. Finally if the oil film is semi-fluid and not quite fixed, if there is slight creeping as was often the case, the particles are redistributed after falling along stream lines where they cohere in strings and bunches, usually without coalescing. This was also observed, and in fact the capillary forces involved are apt to be strong enough to counteract viscosity.

6. *Data.*—I have not thus far spent much time in correcting these defects, chiefly because the new results for the diameters of fog particles are more immediately interesting. Some data are given in Table I.

If the diameters measured are plotted in a chart, together with the results computed from successive exhaustions and coronal aperture s in the older (curve b) and in the more recent (curve a) experiments, the present values again lie between the two curves but now nearer the lower (recent) curve than before, § 4. I shall not pause to interpret the differences which remain, but only to remark that the capillary forces at the area of contact of the droplet, even with the liquid oil film, may transform it to an oblate spheroid and that diffraction at the circular edges of the drops is not excluded. Micrometric data cannot be smoother because the particles are not of a size for the same corona. If the nucleation n_0, obtained from successive isothermal exhaustions and subsidence measurement, be accepted as correct (lower curve a), the ratios of the nucleation found from the different methods tested will be

From subsidence, $a = \cdot0029$,	$d/d_0 = 1\cdot0$	$n/n_0 = 1\cdot0$
from lycopodium ($d = \cdot0032^{cm}$), $a = \cdot0034$,	" $= 1\cdot2$	$n/n_0 = \cdot61$
from diffraction (blue), $a = \cdot0034$,	" $= 1\cdot2$	$n/n_0 = \cdot61$
from micrometer measurement, $a = \cdot0037$,	" $= 1\cdot3$	$n/n_0 = \cdot48$
old results (adiabatic conditions assumed),	" $= 1\cdot6$	$n/n_0 = \cdot24$

Since n is obtained from the cube of d, large differences of this kind are as yet inevitable, particularly as the particles measured in these different cases are not the same.

7. *Graded nuclei.*—The point of special interest which comes out on using the eccentric plate to catch the subsidence during 15 or 30 seconds, and at once examining the deposit, is the result that particles of all sizes are present. By far the greater number, however, have the maximum diameter. These particles are caught from the fog without interference and it is not probable that coalescence or evaporation have been appreciably operative, so long as the corona remains the same throughout the micrometer measurement. The probable

explanation is this: while the pressure decrement is growing from zero to the maximum δp, condensation is taking place on the greater number of particles throughout the whole of this interval. In other words, although the nuclei are graded in size, the greater number exceed a certain dimension and require almost no pressure decrement to induce condensation. These are the particles (diameter exceeding a certain inferior limit) which give character to the *persistent* corona. A minority of the graded particles are below the dimension in question and upon these condensation does not take place until the higher values of the pressure difference are reached, some may even require the full pressure decrement, δp. Thus it is that in the deposit of fog particles, one finds those of diameter $\cdot 001^{cm}$ intermixed with others of smaller diameter, even as far as $\cdot 0002^{cm}$ or less. When fresh phosphorus nuclei are first introduced into the condensation chamber the result is a grey fog, but a relatively small white reddish corona is nevertheless discernable. Accordingly the crop of droplets seen under the microscope contains not only surprisingly small but also relatively large droplets, with all intermediate diameters. Hence the indefinite fog and the small corona. The large olive (g b p) corona and other of the early coronas are very apt to *fade* into a coarse white reddish corona. This is the evaporation of the smaller particles into the larger, which accounts moreover, for the loss of nuclei during the first precipitation, to be caught in subsequent exhaustions. The successive coronas in a series gradually become sharper and the larger particles more uniform, but extremely fine particles are still present even when one approaches the normal coronas. The fine particles, however, belong to coronas so large and diffuse that their coronal effect scarcely modifies the strong coronas of the large particles, even before the former vanish by evaporation.

When I first observed these different sizes of drops caught on a single plate, it seemed not improbable that a difference of the condensational effect of the negative and the positive ions might here be actually in evidence; but as all intermediate sizes are present at the outset, and particularly as large and small droplets still appear together long after all electrification has certainly vanished, this conclusion is not warranted. What continually favors uniformity is subsidence of fog. As the phosphorus nuclei are graded, it is probable that the very fine droplets are due to the initial or primitive nuclei from which the larger nuclei have grown by cohesion; or the fine droplets may be due to air nuclei associated with the phosphorus nuclei. All this will appear in a more minute photographic study of the subject with which I am now engaged, and it will then be further interesting to decide whether the nuclei generated

by the X-rays are not also graded below a certain usually much smaller maximum diameter, and, in general, to ascertain where the nuclei originate. That this maximum diameter will increase with the lapse of time allowed for coherence may be inferred from my experiments with the steam jet: X-ray nuclei will not act upon the steam tube unless a certain time is allowed for growth, as I understand it. The coarse and washed type of coronas obtained with nuclei produced by the X-rays is evidence of graded size, while the fog particles, so far as I have yet caught them, are of varied dimensions. In these cases the X-rays reached the inside of the condensation chamber through its waxed wood walls lined with wet cloth. To obtain a fairly strong and large corona an exposure to the rays lasting 5 to 10 minutes was needed, as the radiation was not very intense. In this interval the original extremely small nuclei are probably undergoing continuous growth, for instance by cohering, so that on exhaustion particles of all sizes* are revealed. In addition to the ragged coronas there is copious rain.

* Under these circumstances it seems reasonable that the time loss of nuclei must at the outset be proportional to the square but finally to the first power of the number, assuming that eventually the large nuclei do most of the catching.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Formation of Ozone.*—When an electric discharge was passed in a tube of fused quartz evacuated to a few millimeters of mercuric pressure, it was noticed by E. Goldstein that an intense odor of ozone was produced in the vicinity of the quartz tube. Potassium iodide and starch paper were quickly made blue by the product. The odor disappeared instantly when the discharge was interrupted. The phenomenon appeared when the gas pressure in the tube was varied rather widely; it was most intense when the light from the tube was brightest. Narrow tubes were found to be preferable to wide ones for the purpose. No odor of ozone was perceptible when glass tubes were used in place of those of quartz. The author believes that the phenomenon is due to the action of ultra-violet rays of very small wavelength, which pass through the quartz glass and convert the oxygen of the air into ozone.

When a U-shaped quartz tube, through which the discharge was passing, was dipped into liquid air, noticeable ozonization did not appear to take place. It is possible that the ozone in the air surrounding a quartz discharge-tube might have been condensed by cooling, but it seemed preferable to make the experiment with oxygen inside of a tube where the production of ozone would probably be greater. Experiments showed that it was possible to convert oxygen entirely into ozone within a Geissler's tube, which, in this case, was made entirely of glass, by cooling a portion of the tube with liquid air and admitting oxygen from time to time in proper quantities. The cooled part of the tube quickly became coated with a blue layer of liquid ozone. When the tube was removed from the liquid air the blue liquid ran down the walls of the tube and collected at the bottom as a blackish-blue liquid. When a part of the tube was kept cool with liquid air the pressure within the tube fell to about $\frac{1}{10}$ mm and this pressure remained constant as long as liquid ozone was present, even when the tube was pumped out as far as possible. This indicated that all of the oxygen was converted into ozone and it showed the tension of ozone at the temperature of liquid air. No spontaneous explosions of the liquid ozone took place during these experiments, such as were observed by Ladenburg when ozone was condensed under atmospheric pressure.—*Berichte*, xxxvi, 3042. H. L. W.

2. *A Peculiar Property of Some Hydrated Salts.*—A. de Schulten observes that, as a general rule, where salts form several hydrates, the hydrate richest in water gives the lower hydrates by successive increases in temperature. For instance, $MgSO_4 \cdot 12H_2O$, at a few degrees above freezing is changed to $MgSO_4 \cdot 7H_2O$, while at 52° $MgSO_4 \cdot 6H_2O$ is formed, and at 132°

$MgSO_4 \cdot H_2O$ is produced. Many other cases of this usual manner of transformation are known. The peculiarity to which attention is called is the behavior of certain hydrates which do not act in the usual way in this respect. Three examples are given. Gaylussite, $CaCO_3 \cdot Na_2CO_3 \cdot 5H_2O$ loses the whole of its water at 100°, while pirssonite, $CaCO_3 \cdot Na_2CO_3 \cdot 2H_2O$, does not undergo any change at 100°, and it is only at a temperature of 130° that it loses the whole of its water. The compound $Mg_3(PO_4)_2 \cdot 22H_2O$, at 100°, quickly loses 18 molecules of water, and then very slowly loses more water, while artificial bobierrite, $Mg_3(PO_4)_2 \cdot 8H_2O$, does not undergo any alteration at 100°. The arseniate $Mg_3(AsO_4)_2 \cdot 22H_2O$, corresponding to the above phosphate loses 17 molecules of water very quickly at 100°, while artificial hoernesite, $Mg_3(AsO_4)_2 \cdot 8H_2O$, does not change at all at 100°.—*Bulletin*, xxix, 724. H. L. W.

3. *Attempts to Prepare Nitrogen Fluoride.* — Several years ago it was announced by Warren that he had prepared a fluoride of nitrogen in oily drops by the electrolysis of ammonium fluoride solution. Moissan failed to produce any such compound by the action of fluorine either on nitrogen or ammonia. Rupp and Geisel have recently attempted to prepare the compound by Warren's method, and by other methods which suggested themselves, and after an elaborate series of experiments were unable to obtain any evidence of its existence. It seems probable that Warren used ammonium chloride, and that the explosive body obtained by him was merely nitrogen chloride.—*Berichte*, xxxvi, 2677. H. L. W.

4. *Quantitative Chemical Analysis;* by the late Dr. C. Remigius Fresenius. Authorized Translation of the Sixth German Edition by Alfred I. Cohn. 2 vols., 8vo, pp. 780 and 1255. New York, 1904 (John Wiley & Sons).—This voluminous work is apparently an absolutely complete translation of the last German edition, which appeared in 1875, twenty-nine years ago. The translator has made a number of additions. In the first part, which is the systematic treatment of the subject, the additions are practically confined to those introduced by Johnson and by Allen, and to be found in the last American edition of 1881. It is to be noticed, however, that modern atomic and molecular weights have been substituted for older ones throughout the work. The second or special part of the book contains occasional additions by the translator of modern methods, and as appendices are added the methods of analysis adopted by the Association of Official Agricultural Chemists, and also Hillebrand's treatise on Rock Analysis.

It is to be regretted that the translator abandoned his original intention of inserting many of the more recent and improved methods of chemical analysis, for space might have been gained for these by the omission of the antiquated methods thus supplanted; but the reverential attitude of the translator was evidently such that it seemed improper to omit anything. However,

it should be observed that a large part of the inorganic analysis of thirty years ago is applicable at the present time, and that this classical work of Fresenius must still be considered the standard reference book on the subject. H. L. W.

5. *The Analytical Chemistry of Uranium;* by HARRY BREARLEY. 8vo, pp. 45. London, 1903 (Longmans, Green & Co.).—This little book deals chiefly with the author's experience in determining uranium, in separating it from the associated elements, and in descriptions of analyses of uranium minerals. In view of the present importance of uranium ores as sources of radium, it seems remarkable that this interesting metal is not mentioned in the book under consideration in the list of elements occurring in pitchblende. It is still more remarkable that the author apparently is not familiar with the discovery of helium, for he mentions nitrogen as a constituent of pitchblende and refers only to Hillebrand's work on this subject. H. L. W.

6. *Chemical Calculations;* by H. L. WELLS. 8vo, pp. 58. New York, 1903 (Henry Holt & Co.).—The first thing noticed on opening this book is the excellent arrangement of the logarithm tables, which are provided with a thumb-index and are exceedingly convenient for such calculations as a chemist usually has to make. There is a table of gravimetric factors for calculating analytical results which is very complete, and a convenient set of tables to be used for gases. Also, a table for calculating indirect analyses, and another to be used in calculating fluxes to form slags. The second part of the book explains briefly, with examples, how the tables are used. H. W. F.

7. *Solar Radiation and the Pressure of Light.*—This subject is discussed in an important paper by Professor POYNTING of the University of Birmingham. The author takes the fourth power law, $R = \delta\theta^4$, where R is the energy radiated per sec. per cm. by a full radiator at temperature θ° A (A stands for the absolute scale) and δ is the constant of radiation. According to Kurlbaum

$$\sigma = 5{\cdot}32 \times 10^{-5} \text{ erg.}$$

Taking the various values given by different observers of the solar constant, Poynting calculates the effective temperature of the sun, and places it between 6000° A and 7000 A—more exactly at 6200° A. The effective temperature of space is then 10° A. If a body, therefore, is raised to a small multiple of 10°—say 60°—the fourth power law of radiation implies that it is giving out and, therefore, receiving from the sun more than a thousand times as much energy as it is receiving from the sky. The sky radiation can, therefore, be left out of account, when we are dealing with approximate results, and bodies in the solar system may be regarded as being situated in a zero enclosure except so far as they are receiving radiation from the sun.

On the supposition that the moon does not conduct inward, its upper limiting temperature is found to be 371° A, just below the temperature of boiling water. Langley estimated the tempera-

ture of the moon to be a few degrees above the freezing point. On the supposition that three-fifths of the heat is conducted inward, Poynting calculates the upper limit at 297° A. He also calculates the temperature of fully absorbing spherical bodies of 1^{cm} in diameter at the distance of the earth from the sun and finds the temperature $\theta = 300°$ A. This will be the temperature of bodies smaller than 1^{cm}, so long as they are not too small to absorb all the radiation falling upon them. The variation of temperature with distance from the sun is next estimated; the author regards it as highly probable that the temperature of mass is everywhere below the temperature of freezing point of water. The only escape from this conclusion is to suppose an appreciable amount of heat issuing from his surface. Considering a comet as made up of small particles of the order 1^{cm} or less, these particles twenty-three million miles from the sun would have the temperature of melting lead, and at three and three-quarters million miles, the temperature of cast iron (1500°).

Poynting then discusses the value of the radiation pressure. Bartoli showed that a pressure must exist without any theory in regard to the nature of light, beyond a supposition that a surface can move through the ether, doing work on the radiation alone, and not on the ether in which the radiation exists. The most interesting part of the paper is that which deals with a comparison between mutual gravitation and radiation pressure of small bodies. Poynting calls attention to the fact, that if the radiating body is diminished in size the radiation pressure due to it also decreases less rapidly than the gravitative pull which it exerts. The radiation decreases as the square of the radius of the emitting body and its gravitational pull as the cube. It is also noted that equality of action and reaction does not hold between the radiating and receiving bodies alone. The ether is material and takes its part in the momentum relations of the system. Two globes of water, probably nearly full absorbers at 300° A, will at that temperature neither attract nor repel each other if their radii are about 20^{cm}. Small particles of the order 1^{cm} radius would be drawn into the sun even from the distance of the earth in times not large compared with geological times. Near the sun the effects are vastly greater. The application to meteoric dust in the system is obvious. The entire paper pleads for an extension of our idea of matter to include the medium. Bodies do not act upon each other; each sends out a stream of momentum into the medium surrounding it. Some of this momentum is ultimately intercepted by the other, and in its passage the momentum belongs neither to one body nor to the other. The action on one of the bodies is equal and opposite to the reaction on the light-bearing medium contiguous to it.—*Phil. Trans. of Roy. Soc.*, Series A, vol. ccii, pp. 525–552. J. T.

8. *Blondlot's n-rays.*—Blondlot describes a new species of rays which he terms *n*-rays. These rays are given out by the Auer-burner or still better by the Nernst lamp. They penetrate alumi-

num: are absorbed by the smallest layer of water: acting like long heat waves. While they are absorbed by cold platinum they easily penetrate red-hot platinum. These *n*-rays radiate from the Nernst lamp long after this lamp is extinguished, and silica exposed to the sun's rays show these rays.

Dr. O. LUMMER calls attention to the physiological effects on the retina produced by experiments similar to those of Blondlot, and suggests that the *n*-rays are merely ghostly images produced on the structure of the retina and its nerves by the method of observation pursued by Blondlot. The phenomena observed by the latter appear to be the result of the struggle between the rods and cones of the retina in the effort to fix our vision in the dark.—*Deutsch. Physikalisch. Gesellsch.*, v Jahrg., Nr. 23. J. T.

9. *The Rowland Effect.*—The magnetic effect of electric convection has been tested by Wilson, Adams and Pender and Eichenwald. In addition to these investigators is now HIMSTEDT, who publishes a quantitative investigation in the hope of adding cumulative evidence. One series of trials gave for the value of v, the ratio of the electrostatic to the electromagnetic units, 3·04; and a second series, 2·99. Himstedt's experiments, therefore, confirm Rowland's results.—*Ann. der Physik*, No. 1, 1904, pp. 100–123. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey.*—The following publications of the U. S. Geological Survey have recently been received:

MONOGRAPH XLV. The Vermilion Iron-Bearing District of Minnesota, by J. MORGAN CLEMENTS. 447 pp., 13 pls., 23 figs., 26 atlas sheets. This is the fifth of the monographs published by the Survey which deal with the geology of the various iron-producing districts of the Lake Superior region. The ore deposits, which make the region of great interest, are strikingly like those of the Marquette district. The ore bodies are usually found either at the bottom of a highly folded chert or jasper formation and resting upon an underlying igneous mass folded into a synclinal trough, or within the iron-bearing formation and resting upon intercalated silts or intruded dikes of igneous rock. The mode of origin assigned to the ore bodies is the same in general as that given for the other districts, and which has been described in detail by Van Hise in the monograph on the Penokee district.

The monograph is well illustrated and is accompanied by an atlas giving detailed maps of the area. A useful feature is the introductory outline, which gives a brief summary of the matter treated in the book. W. E. F.

BULLETIN No. 211. Stratigraphy and Paleontology of the Upper Carboniferous Rocks of the Kansas Section, by GEORGE I. ADAMS, GEORGE H. GIRTY and DAVID WHITE. 123 pp., 1903. The area covered is situated in Eastern Kansas, and represents

exposures of a continuous series of beds; sandstones and shales and interbedded limestones, of 3250 feet thickness. An erosional unconformity limits them below, somewhere in the lower part of the Upper Carboniferous, and the uppermost formations are regarded as Permian.

Forty-seven distinct formations are recognized, giving an average of about seventy feet to a formation. No attempt is made by the author to form more comprehensive divisions of the whole, as was done by Haworth and by Prosser, since the sedimentation is found to be continuous, oscillating between sets of dominantly calcareous beds and sets of beds dominantly shaly, the fossils occurring more richly in the limestone or calcareous formation. "*The evolution of the latest from the earliest faunas*," is said, by Girty, to be "*without marked interruption at any point so that subdivisions appropriate for recognition are not clearly apparent.*" No classification of the beds seems to be especially favored by the evidence of invertebrate paleontology.

David White reports on the Plants from the Kansas beds and finds the majority of them typical Coal Measure (Pennsylvanian) species, while those from the Marion and Wellington formations at the top of the section, identified by Sellards, indicate Permian age. H. S. W.

Folio No. 94. Brownsville-Connellsville folio, Pennsylvania, by Marius R. Campbell. This geological map and its explanation is an admirable example of the thorough work produced by the Survey. The region covered is in southwestern Pennsylvania, in the midst of rich coal and gas fields. The survey is based upon triangulation surveys, and topography of the surface as well as the underground structure are elaborated in detail. Numerous stratigraphic sections of mines (92 are figured and described) are given and the productive horizons of numerous gas wells determined. The classification of the formations is the usual one, with the thickness for this region as follows, viz:

? Permian	Dunkard	300′
Pennsylvanian	Monongahela	310–400′
	Conemaugh	600′
	Allegheny	280′
	Pottsville sandstone	150′
Mississippian	Mauch Chunk	150′
	Pocono	400′

The Pocono sandstone is at its top developed into a siliceous limestone. In the midst of the Mauch Chunk, the Greenbriar limestone is developed as a lentil from 0 to 30 feet thick, fossiliferous; it is shown to be of Chester age. An unconformity is recognized at the base of the Pottsville, the lower member of which is believed to represent the Conoquenessing sandstone. In the Conemaugh formation a crinoidal limestone (the Ames limestone), four feet thick, is seen below the Morgantown sandstone.

The upper Coal Measures (Monongahela) contains the important Pittsburg, Redstone, Sewickly, Uniontown and Waynesburg coals. Between the Sewickley and Uniontown the so-called "great limestone" occurs to which the name Benwood limestone is applied. Many productive gas wells are scattered over the Brownsville quadrangle, statistics of which are given. H. S. W.

2. *On the Geology of the Hawaiian Islands;* by WM. H. DALL. (Communicated.)—In the article by Dr. Branner on the Geology of the Hawaiian Islands, in the October number of the Journal, he comes (pp. 306–309) to a different conclusion with regard to the calcareous layers interstratified with the tuffs of Diamond Head, Oahu, from that to which I was led in 1899. This difference is probably due to the fact that Dr. Branner did not see all the area which I examined and reasoned from certain beds which he did see and which are doubtless of a different nature from those to which I referred.

I found oysters, *Chama*, and numerous corals, fossilized as they grew, and still adhering to the nearly horizontal surface of the continuous thin sheet of lava which formed the basis of an area of very considerable extent entirely outside of the slope of the tuff cone but apparently continuous under it. The particular horizon which I examined formed the top of the ground for a considerable distance inland, and the circumstances are entirely incompatible with the idea of a subaërial formation. That there may be subaërial formations around Diamond Head in some places is highly probable, but that is another story.

Smithsonian Institution, Washington, D. C., Dec. 15, 1903.

3. *Geological Commission, Cape of Good Hope;* G. S. CONSTORPHINE, Director. Annual Reports, 1900, 1901, 1902.—The geological work for 1900 was mainly in the district west of the Karroo plateau. A new formation (the "Ibiquas Series") is reported lying between the Malmesbury beds and the Table Mountain sandstone. Glaciated pebbles were found in the Table Mountain series (early Devonian). The underlying unconformity of the Dwyka conglomerate (this Journal, xiii, 413) is changed to conformity at the south. Dolerite sheets and dikes cut the Paleozoic sediments. Announcement is made of the discovery of a new Mesozoic swimming reptile.

Owing to the Transvaal war, the geologists of the Commission spent the season of 1901 along the southeast coast line making a general survey of Transkei and Pondoland with special studies of the Cretaceous of Pondoland and of the igneous rocks (granite, diorite, dolerite) of Kentani. The map shows a remarkable adjustment of streams to the diorite. During 1902 Mr. E. H. L. Schwartz made a survey of parts of the Matatiele Division in Griqualand East. Perhaps the most interesting part of his work is the description of a row of 19 volcanic necks trending northeasterly, from which issued the lavas which form the crest of the Drakensbergs. The cones and flows are deeply eroded or destroyed on their east (wet) side but are well preserved on their west side.

"The sedimentary rocks through which the chimney is pierced never show the least shattering or plication." A petrological examination of these volcanics (pp. 65–96) shows them to be dolerites and basalts. The common type is the "amygdaloidal melaphyre" with long, narrow branching vesicles as first described by Cohen (Neues Jahrbuch, 1875). Mr. A. W. ROGERS was appointed acting geologist in 1902, and, in addition to his official duties, surveyed parts of Beaufort West, Prince Albert and Sutherland Divisions. A classification of strata has been adopted for Cape Colony which in outline is as follows :

Superficial Deposits.	Dunes; Alluvium, Laterite, Esturine and River Deposits.
	Pondoland Cretaceous Series
	Uitenhage Series
Karroo System (Permian Jurassic ?)	Stormberg Series
	Beaufort Series
	Ecca Series
	Dwyka Series
Cape System (Devonian ?)	Witteberg Series
	Bokkeveld Series
	Table Mountain Series
Pre-Cape Rocks In the south and west of Cape Colony	Ibiquas Series
	Congo Series
	Malmesbury Series
Pre-Cape Rocks In north and northwest of Cape Colony	Matsap Series
	Griqua Series
	Campbell Rand Series
	'Kreis Series
	Namaqualand Schists ?

The vertebrate fossils from these series are now being examined by Professor Seely ; the plants by Mr. Seward; the invertebrates by Mr. Lake, Mr. Kitchen and Mr. Chapman. Until these fossils are reported on, correlation will not be attempted.

It is to be regretted that suitable maps and sections do not accompany these reports.

4. *Geological Society of South Africa* (Transactions, vol. vi, parts 1, 2, 4).—The most recent publications of the Geological Society of South Africa contain papers by E. P. RATHBONE on the Geology of the DeKaap Goldfields ; by J. P. JOHNSON on sections at Shark River and the Creek, Algoa Bay ; by G. S. CORSTORPHINE on the age of the Central South African Coalfield; by G. A. F. MOLENGRAAFF on the Vredefort Mountain Land. The Vredefort region consists of a granite intrusion with zones of metamorphosed sediments. In part 4 are papers by J. P. JOHNSON, on the Discovery of Implement-bearing beds near Johannesburg in which Eolithic, Palaeolithic and Neolithic forms are described; by A. R. SAWYER on the Origin of the Slates on the Rand and on the Vredefort Granite Mass; by F. H. HATCH on the Black Reef Series; by J. KUNTZ on Pseudomorphosis of Quartz Pebbles into Calcite.

5. *The Action of Radium, Roentgen Rays and Ultra-Violet Light upon Minerals and Gems.*—An article by G. F. KUNZ and C. F. BASKERVILLE upon this subject is given in full in the issue of Science for Dec. 18, 1903. A number of minerals, including diamond, willemite, kunzite, pectolite, topaz, fluorite, autunite, etc., were subjected to these different forms of radiation and a considerable part found to respond. Of these, willemite, the violet-colored spodumene called kunzite and diamond were the most responsive to all forms of activity; the possibility of the presence of some undetermined element with the willemite (also hydrozincite, etc.) is suggested. In the case of minerals from Borax Lake, California, of different composition but which all phosphoresced with ultra-violet light, though not with radium, the existence of an element explaining this property is also suggested. The whole subject is one calling for much additional investigation.

6. *Optical Characters of Anthophyllite: a Correction;* by C. H. WARREN. (Communicated.)—The writer wishes to make a correction regarding the optical orientation of the anthophyllite from Rockport, Mass., described in this Journal, vol. xvi, November, 1903, p. 341. The orientation should be: $c' = \mathfrak{c}$, $a = \mathfrak{a}$, $b = \mathfrak{b}$, thus making the mineral optically negative.

The error was due to the fact that a quartz wedge was used in making the determinations, which was cut with the vibration direction of fastest ray opposite to that of this ray in the wedges to which the author had always been accustomed. Until very recently no occasion had arisen to use this particular wedge for the determination of a known mineral and so the error remained unnoticed.

7. *Chemical Composition of Igneous Rocks expressed by means of Diagrams;* by J. P. IDDINGS. U. S. Geol. Surv. Professional Paper, No. 18, Washington, 1903, 4°, 92 pp., VIII pl.—The author of this paper was one of the first petrographers to express the chemical relationships of igneous magmas, revealed in their chemical analyses, by graphic means. In recent years we have seen this instrument used by different petrographers in a variety of ways to develop special features, but never before has it been employed with so great a breadth of scope and on a plan so comprehensive as in the present work. The idea is to express pictorially to the eye the mutual chemical relations of all analyzed igneous rocks. For this purpose a double diagram method is used. Each analysis has its molecular ratios calculated and these are referred to a system of axes, and the points on the axes connected with each other by lines. The triangles thus formed are tinted with different colors and this enables the eye at a glance to perceive the relations of the molecular oxides and their capacity for forming feldspathic and ferromagnesian molecules. These are the individual diagrams. The small individual diagrams so formed are then placed in a very large diagram in which their centers or zero points are referred to a set of rec-

tangular axes in which the abscissas are the percentages of silica and the ordinates are the ratios obtained by dividing the molecular proportions of the combined alkalies by the molecular proportions of the silica. This point forms the locus of the small diagram.

In the first table are given the small colored diagrams of over 950 analyses of igneous rocks having over 28 per cent of silica, selected to show all possible variations. The table is continued and completed in plate viii, which shows the rocks with less than 28 per cent of silica. In another table are shown the loci of the alkali-silica ratios of over 2000 analyses; in this case the individual diagrams are omitted and the loci shown by simple dots. In other plates are shown the diagrams of analyses, disposed as in plates i and viii, divided and arranged according to the new quantitative chemical classification recently proposed by Cross, Iddings, Pirsson and Washington.

There are many interesting and instructive features shown by these diagrams which must be seen to be appreciated. Perhaps the most convincing thing they prove is the impossibility of any "natural" classification of igneous rocks and that any division lines must of necessity be wholly arbitrary ones.

The work is certainly a tribute to the patience and industry of the author, a reflection that is forced home when one thinks of the vast number of analyses that have been computed and carefully arranged in these diagrams. Whatever evidence they present certainly does not lack weight for want of facts to sustain it. L. V. P.

8. *Petrographisches Prakticum;* von R. Rheinisch. Part II, Gesteine. Pp. 180, 8°. Berlin, 1904 (Gebr. Borntraeger).—The first part of this work has been previously noticed in this Journal (vol. xiii, p. 243, 1902). The object of this elementary treatise is to afford help to the beginner in the study of rocks; it is not intended as a complete text-book and its use demands some previous acquaintance with the elements of the science. The igneous rocks, the sedimentary rocks and the crystalline schists are briefly treated. The "dike rocks" are not assigned a separate position but are mentioned under the abyssal granular types. The system of classification followed is essentially that of Zirkel. Each rock is briefly described, its mineral composition mentioned, a few mass analyses given and the more important localities, especially the German ones, stated. The book is well gotten up and appears carefully written and will no doubt prove useful in Germanic countries. The thought that strikes one in connection with it is, that since a knowledge of the subject and the use of the microscope are implied, why not use one of the larger text-books at once in which all phases of the subject are covered and more information given. L. V. P.

9. *Les Roches alcalines caracterisant. la Province pétrographique d'Ampasindava;* par A. Lacroix. Nouv. Archiv. du Muséum, 4 ser., v, 4°, pp. 171–254, pl. 14, 1903.—It will be

recalled that some time since Professor Lacroix published an important memoir upon an interesting series of alkaline rocks from the northwest coast of Madagascar as noticed in this Journal, vol. xiv, page 396, 1902. In the present work a new series of similar rocks from other localities in the same province is described with analyses by PISANI, syenites, foyaites, tinguaites, monzonites, etc., which thus extend the limits of this petrographic province in a most interesting way. L. V. P.

10. *Notes on the Rocks of Nugsuaks Peninsula and its Environs, Greenland;* by W. C. PHALEN. Smithson. Misc. Coll. Quart. Issue, vol. xlv, pp. 183–212, 1904.—A petrographic description accompanied by analyses of rocks collected in 1897 by Messrs. Schuchert and White. The rocks are mostly granular crystallines, granite, syenite, diorite, etc., and there is a complete description of the iron-bearing basalt. The work is carefully done and adds to our knowledge of the petrography of the northern lands. L. V. P.

11. *Monograph of the Coccidæ of the British Isles;* by ROBERT NEWSTEAD. Volume I, 1901; pp. xii+220; text figures 20; 39 plates. Volume II, 1903; pp. 270; text figures 7; 42 plates. London (printed from the Ray Society).—The second and final volume of Mr. Newstead's careful and very praiseworthy monograph of the British scale insects has just been published. The entomological monographs published by the Ray Society have not always been of the first rank, but this one of Mr. Newstead's deserves very great praise. Many of these Ray Society monographs have been devoted to the consideration of the fauna of the British Isles, and from its title this would seem to be of equally limited scope. As a matter of fact, the author has only included species which have actually been found living in Great Britain and Ireland, but with the Coccidæ the conditions are such that a far more general interest attaches to this monograph than any of the others which have been geographically so limited. Perhaps the majority of the Coccidæ of the world have, through the constant interchange of plants, become practically cosmopolitan. It is difficult with the majority of species at this late date to decide the probable original home. The result is that by far the larger number of species treated by Mr. Newstead have been introduced into Great Britain, and have established themselves there. To illustrate the interest which American investigators will have in this monograph, of the thirty-six species of Diaspinæ treated in volume i, thirty occur also in the United States, and, of the remaining six, three have been found only in greenhouses in Great Britain and are probably species introduced from some other part of the world. Compared with the world fauna in the Coccidæ, however, the number of species treated in the monograph is, of course, small, and hence some of the generalizations made by the author as to generic distinctions and those of higher groups will possibly be open to criticism when larger series are studied. It seems to the writer, for example,

that an error has been made in confusing the species of the true genera Diaspis and Aulacaspis, since the arrangement of the dorsal tubular spinnerets in the female has been used as the striking character with these and some allied genera, rather than the more important structural characteristics of the anal plates. Some day I fear there will be a general untwisting of Mr. Newstead's assignment of the species of this genera.

An important contribution to the literature of the much-discussed male of *Lecanium hesperidum* occurs in volume ii, and Mr. Newstead describes the second stage and the puparium of what is undoubtedly the true male of this species. He indicates that the male, as was quite to be expected, belongs to the true Lecanium type, and that the alleged discovery by Moniez had probably reference to one of the Chalcidid parasites which universally infest females of this species.

The many illustrations, and especially those upon the plates, all done by Mr. Newstead himself, are better done than any figures of Coccidæ which have heretofore been published.

The revised nomenclature of the Coccidæ, as displayed by Mrs. Fernald in her Catalogue of the Coccidæ of the World, and which must probably be accepted, is not followed in the text proper, but in an appendix to volume ii it receives proper recognition.

L. O. HOWARD.

12. *Catalogue of the Lepidoptera Phalænæ in the British Museum*, Vol. IV. Catalogue of the Noctuidæ; by Sir George F. Hampson. Pp. xx, 689, with an accompanying part containing plates lv–lxxvii. London, 1903.—The issue of Part IV of the British Museum Catalogue of Moths will be welcomed by all interested in this subject. It contains descriptions of some 1200 species of the Agrotinæ, the first of the fifteen sub-families of the Noctuidæ. The plates, reproduced by trichromatic photography, are very beautiful and show the perfection to which the process has been brought.

13. *General Zoology;* by C. W. Dodge. 482 pp., 379 figs. (American Book Company.)—Professor Dodge has revised and re-arranged "Orton's Comparative Zoology" in a way which is highly satisfactory to the teacher and to the general student.

III. Miscellaneous Scientific Intelligence.

1. *American Association.*—The fifty-third meeting of the American Association for the Advancement of Science was held at St. Louis during the week from December 26, 1903, to January 1, 1904. Dr. Carroll D. Wright was President of the meeting. The address of the retiring president, Dr. Ira Remsen, was delivered on December 28th, on the subject "Scientific Investigation and Progress." This address is given in the issue of Science for January 1 and the following numbers of the same periodical give a full account of the proceedings. Affiliated societies to the number of twenty-one held meetings in conjunction with the

Association. The total attendance, including 81 in the societies, was 466. The new policy of holding winter meetings, with its obvious advantages and disadvantages, was upheld and the next meeting appointed for Philadelphia, beginning Tuesday, Dec. 27, 1904. New Orleans was recommended for the meeting two years hence. The following officers were elected for the Philadelphia meeting :

President: W. G. Farlow, Cambridge, Mass. *Vice-Presidents:* Section A, Alexander Ziwet, Ann Arbor, Mich. ; Section B, W. F. Magie, Princeton, N. J. ; Section C, L. P. Kinnicutt, Worcester, Mass. ; Section D, D. S. Jacobus, Hoboken, N. J. ; Section E, E. A. Smith, University of Alabama; Section F, C. Hart Merriam, Washington, D. C.; Section G, B. L. Robinson, Cambridge, Mass. ; Section H, Walter Hough, Washington, D. C.: Section I, M. A. Knapp, Washington, D. C. ; Section K, H. P. Bowditch of Boston. *General Secretary*, Charles S. Howe, Cleveland, Ohio. *Secretary of the Council*, C. A. Waldo, Lafayette, Indiana.

2. *Carnegie Institution of Washington, Year Book, No. 2, 1903.* Pp. lix, 311. Washington, January, 1904 (published by the Institution).—This second volume from the trustees of the Carnegie Institution will be widely welcomed since all the facts in regard to the administration of this fund cannot but be of great interest to every one concerned with the progress of scientific research of the country. It is a matter of general congratulation that this unique work has been initiated and thus far carried on with so much liberality and wisdom. The opening part of the volume (pp. i–lix) contains administrative matters including the minutes of the Board of Trustees, the Report of the Executive Committee on the work of the year and memorials of Abram S. Hewitt, William E. Dodge and Marcus Baker. Following this are a series of seven papers including reports on southern and solar observatories, reports relating to geophysics, original memoirs in several departments.

The list given of the grants, aggregating nearly sixty, made during the year out of the sum of $200,000 set apart by the Trustees at its last annual meeting, shows the wide range of scientific inquiry aided by the Carnegie Institution; with each statement a brief account of the results thus far obtained is included. It is interesting to note that the demand upon the funds of the Institution is much greater than it can meet ; thus it is stated that from the beginning until Oct. 31, 1903, the total number of requests for aid was 1,042 and these called for an expenditure of $2,200,398. To this sum are to be added the grants recommended by the Advisory Committee aggregating $911,500, thus giving a total possible expenditure of $3,111,898. Although but a small part of the demands for assistance in research can be favorably acted upon, the total amount of good that may be expected from the money actually paid out is very large indeed.

3. *Physikalisch-chemisches Centralblatt.*—The first number of the Physico-chemical Review, announced on p. 475 of the last

volume, has recently been issued under date of December 15, 1903. It contains thirty-two pages and gives seventy-nine abstracts, of physical and chemical papers, in German, French or English, according to their original source. It is much to be hoped that this new review may meet with the general coöperation and support which it deserves.

4. *A Description of the Brains and Spinal Cords of Two Brothers dead of Hereditary Ataxia;* by LEWELLYS F. BARKER. The Decennial Publications of the University of Chicago, First Series, Vol. X, 38 pp., 4to, with twelve plates. Chicago, 1903. (The University of Chicago Press.)—This memoir gives the results of an examination, in part microscopic, of the brains and spinal cords of two brothers, who died of hereditary ataxia. These were cases XVIII and XX of the Series in the family described by Dr. Sanger Brown, who gives here a clinical introduction. Twelve plates with forty-six figures follow the text.

5. *Field Columbian Museum.* — Publications 79, 80 of the Zoological Series, Vol. III, Nos. 12, 13, have recently been issued. The former, pp. 199–232, contains a list of mammals collected by Edmund Heller in Lower California, with descriptions of apparently new species. The latter, pp. 233–237, gives descriptions of apparently new species of *Heteromys* and *Ursus* from Washington and Mexico. Both papers are by D. G. Elliot.

6. *The Planetary System;* by F. B. TAYLOR. 268 pp. Published by the author, Fort Wayne, Indiana.—If Newton's solution of the problem of three bodies were correct it ought to yield a general law for the stability of inner satellites. His analysis, however, shows only indeterminate stability. The theory presented by Mr. Taylor is claimed to yield a law of determined stability of satellites and hence a logical theory for the structure and growth of the solar system.

7. *Metallic Ornaments of the New York Indians;* by W. M. BEAUCHAMP. Pp. 120. Albany, 1903. (New York State Museum, F. J. H. Merrill, Director: Bulletin 73, Archæology 8; Bulletin 305 of the University of the State of New York.)—The number and diversity of Indian ornaments here described will surprise and interest the reader not previously informed on the subject. Upwards of four hundred figures on thirty-seven plates are required for adequate illustration.

8. *Queries in Ethnography;* by A. G. KELLER. 70 pp. (Longmans, Green & Co.)—Professor Keller has prepared an admirable list of queries by use of which observations of travelers and missionaries may be made with such accuracy and pertinency as to be of definite scientific value.

Knowledge Diary and Scientific Handbook for 1904, containing original descriptive articles on the camera applied to science in Astronomy, Microscopy, Natural History; practical work with a small telescope; some uses of the microscope; practical meteorology; the optical constants of lens combinations, and Monthly Astronomical Ephemeris, etc. Pp. 1–420, 85–108. Issued in conjunction with "Knowledge." London (Knowledge Office, 326 High Holborn).